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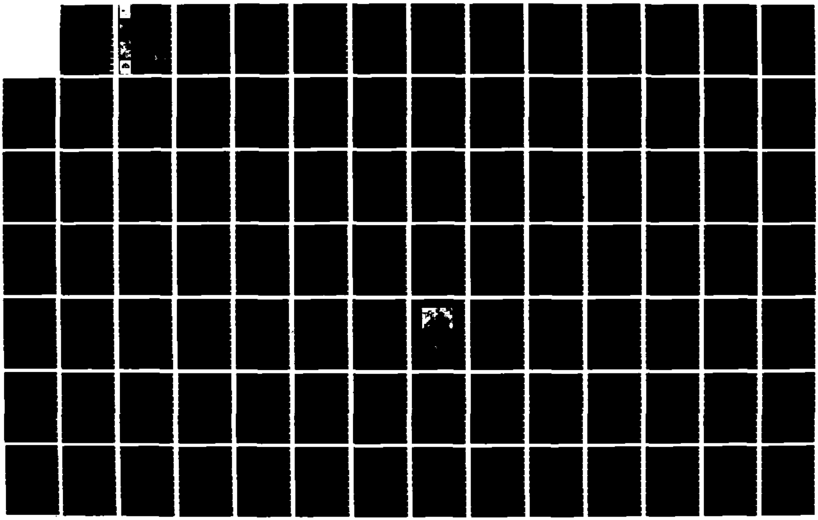

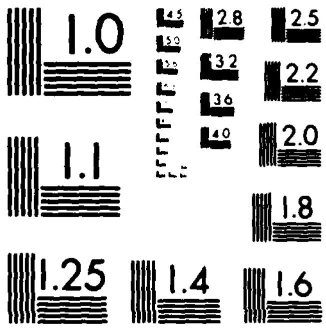

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TECHNICAL REPORT SL-86-10

VARIATIONS IN CEMENTITIOUS MEDIA

by

Ronald E. Reinhold, Rudolf E. Richter, Alan D. Buck, Katharine Mather, Bryant Mather, James E. McDonald

Structures Laboratory

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A total of 59 cements, 12 fly ashes, 19 silica fumes from 16 sources, 3 natural pozzolans, and 1 ground granulated iron blast-furnace slag, and laboratory combinations of these materials were studied by a combination of physical, chemical, and petrographic methods. Creep data were obtained for 17 pastes made using some of these materials.

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PREFACE

Authority for this investigation was given by letter from Mr. J. A. Rhodes, Headquarters, US Army Corps of Engineers (USACE), dated 25 September 1975, subject: "Variations in Cementitious Media," Work Unit 31345. All work was accomplished at the Concrete Technology Division (CTD) (formerly the Concrete Laboratory), Structures Laboratory (SL), US Army Engineer Waterways Experiment Station (WES) under the general supervision of Mr. Bryant Mather, Chief, SL. Project leader was Mrs. Katharine Mather, Chief, Engineering Sciences Division, Concrete Laboratory, at the time of this work.

Funding for the preparation and publication of this report was provided from those allocated to the Technical Surveillance function described in Engineer Regulation 1110-1-2002, Cement and Pozzolan Acceptance Testing, dated 11 November 1977, as authorized by Mr. Robert Philleo, Headquarters, USACE, January 1983.

This report was compiled under the general supervision of Mr. Bryant Mather, Chief, SL, and Mr. John M. Scanlon, Jr., Chief, CTD, and under the immediate supervision of Mr. Richard L. Stowe, Chief, Materials and Concrete Analysis Group, by Messrs. R. E. Reinhold, R. E. Richter, and A. D. Buck, who dealt with the physical, chemical, and petrographic testing, respectively. The participation and assistance of many other present menbers of the CTD staff and former members including Katharine Mather and W. G. Miller are acknowledged. Mr. J. E. McDonald prepared the report of the creep tests.

COL Allen F. Grum, USA, was Director of WES. Dr. Robert W. Whalin was Technical Director.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
calories per gram	4.184	kilojoules per kilogram
Fahrenheit degrees	5/9	Celsius degrees or Kelvins*
inches	2.54	centimetres
pounds (force) per square inch	6.894757	kilopascals
pounds (mass)	0.4535924	kilograms
quarts (US liquid)	0.9463529	cubic decimetres

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use $K = (5/9)(F - 32) + 273.15$.

VARIATIONS IN CEMENTITIOUS MEDIA

PART I: INTRODUCTION

1. When this project was started in 1975, it was recognized that the cement industry in the United States, even as other industries, was in, or about to be in, a state of change due to the need to become less energy-intensive. Changes such as use of dry-process plants, kilns with preheaters, and kilns with calciners were already being made. In addition, there was recognition of the likelihood of increased use of blended cements incorporating granulated slag or pozzolans such as fly ash or natural pozzolans as another means of conserving energy. The intent of the investigation was to look ahead at changes in production and use of cementitious materials as these might affect the properties of paste, mortar, and concrete.

2. The project plan contemplated obtaining a wide range of blended cements, companion portland cements, granulated iron blast-furnace slags, fly ashes, natural pozzolans, and other pozzolans and subjecting them to rather complete characterization tests as discrete materials and in mortars. Materials were to be eliminated along the way if the tests indicated this was proper. Following the characterization stage, three portland-pozzolan cements and their companion portland cements were to be selected along with at least one of each type of blending material for possible use in concrete. After consideration of these selections, they were to be used singly or in combination in concrete mixtures followed by extensive testing of concrete specimens. The stated objective of the project plan dated 30 September 1975 was "to study the effects of changes in composition, constitution, and fineness of cementitious media, or any two or three of these, on strength-gain, durability in freezing and thawing of air-entrained concrete, permeability, volume stability (drying shrinkage and restrained expansion), creep, thermal stability, effect of curing temperatures, and other concrete properties strongly affected by the nature of the hydraulic binder."

3. After the project was under way and there was better realization of the numbers of candidate materials available, it was decided that the purpose would be better served if the materials elimination phase were deleted and as many relevant materials were tested as resources permitted. This decision was

made during periodic review of this project by members of the laboratory staff, representatives of OCE, and OCE consultants. This meant that the objective as stated above had to be modified. Major changes were that more materials than anticipated were tested, none were deleted, and no concrete mixtures were made. The planned tests that were deleted were those for resistance to freezing and thawing in air-entrained concrete, permeability, thermal stability, and effect of curing conditions.

PART II: SAMPLES

4. Physical tests, chemical analysis, and petrographic examinations were made on a group of 59 cements, 12 fly ashes, 3 natural pozzolans, 19 silica fumes (from 16 sources), and 1 ground granulated iron blast-furnace slag, and combinations of these materials to characterize them. These materials are identified below with alphabetical groupings by location within each type of material:

Cements

Serial No.	Cement Type	Process	Fuel Source	Source
RC-705	Portland II	Dry	Coal	Alabama 1*
RC-714	Portland I	Dry	Coal	Alabama 2*
RC-751	Portland I	Wet		Alabama 3*
RC-752	Blended IS	Wet		Alabama
RC-731	Portland I	Dry	Coal, 19% Gas, 81%	Arizona 1
RC-732	Blended IP	Dry	Coal, 19% Gas, 81%	Arizona
RC-763	Portland II	Dry		Arizona 2
RC-764	Portland II	Preheater		Arizona
RC-715	Portland I	Dry Preheater	Coal, 7% Gas, 93%	Colorado
RC-753	Portland II	Dry Preheater	Coal, 7% Gas, 93%	Colorado
RC-754	Portland II	Dry Preheater	Coal, 7% Gas, 93%	Colorado
RC-832	Portland V	Dry Preheater	Coal, 7% Gas, 93%	Colorado
USAECE-IC-1	Blended (Slag)			Germany 1
USAECE-IC-2	Blended (Slag)			Germany 2
RC-733	Portland I	Dry process Preheater	Coal, 2% Gas, 37% Oil, 61%	Georgia
RC-765	Portland I			Iceland
RC-766	Portland I			Iceland
RC-725	Portland I	Dry		Illinois
RC-726(2)	Blended IP	Dry		Illinois
RC-772	Portland II	Dry Preheater		Kansas

* Different plants from the same state.

Serial No.	Cement Type	Process	Fuel Source	Source
RC-755	Portland V	Wet		Manitoba, Canada
RC-756(2)	Portland I			Maryland
RC-761	Portland I			Maryland
RC-758	Blended IS	Wet		Michigan 1
RC-719	Blended IP	Wet	Coal	Michigan 2
RC-720	Portland I	Wet		Michigan 2
RC-734	Portland I	Wet	Coal	Michigan 2
RC-735	Blended IP	Wet	Coal	Michigan 2
RC-829	Portland I	Wet	Coal	Michigan 2
RC-830	Blended IP	Wet		Michigan 2
RC 688(2)(3)	Portland I	Wet	Gas	Mississippi
RC-721	Blended IP	Wet	Coal	Missouri
RC-722	Portland I	Wet		Missouri
RC-738	Portland I	Wet	Coal	Missouri
RC-739	Blended IP	Wet	Coal	Missouri
RC-740	Blended IP	Made with bottom ash	Coal	Missouri
RC-831	Portland II			New York
RC-746	Portland I	Wet and Dry Preheater	Coal	Ohio
RC-769	Blended IS	Dry		Pennsylvania 1
RC-770	Portland I	Dry		Pennsylvania 1
RC-833	Blended IS	Wet		Pennsylvania 2
RC-834	Portland I	Wet	Coal	Pennsylvania 3
RC-716	Portland I	Wet	Gas Oil	South Carolina
RC-717	Blended IP	Wet	Gas Oil	South Carolina
RC-729	Portland I	Wet	Gas/Oil	South Carolina
RC-730	Blended IP	Wet	Gas/Oil	South Carolina
RC-741	Portland I	Wet	Coal	Tennessee
RC-742	Blended IP	Wet	Coal	Tennessee
RC-736	Portland I/II	Dry Preheater	Gas	Texas
RC-737	Portland III	Dry Preheater	Gas	Texas
RC-744	Portland I	Wet	Gas/Oil	Texas
RC-745	Blended IP	Wet	Gas/Oil	Texas
RC-773	Blended IP	Wet	Gas/Oil	Texas

Serial No.	Cement Type	Process	Fuel Source	Source
RC-807	Blended IP, MS	Wet	Gas/Oil	Texas
RC-807(A)**	Portland I	Wet	Gas/Oil	Texas
RC-718	Portland I/II	Wet Short Kiln	Gas	Washington

Pozzolans

Serial No.	Class	Produced from	Source
	Mineral Admixtures		
AD-518	Pozzolan N	Volcanic glass	California
AD-516	Pozzolan N	Volcanic ash+	Greece
AD-515	Pozzolan N	Volcanic ash	Oregon
AD-513	Fly Ash C	Lignite	Colorado
AD-510	Fly Ash C	Lignite	Minnesota
AD-509	Fly Ash F	Lignite	North Dakota
AD-506	Fly Ash F	Lignite	Texas
AD-577	Fly Ash F	Lignite	Texas
AD-512	Fly Ash F	Subbituminous coal	Iowa
AD-505	Fly Ash F	Subbituminous coal	Missouri
AD-507	Fly Ash F	Subbituminous coal	Missouri
AD-511	Fly Ash F	Bituminous coal	Georgia
AD-560	Fly Ash F	Bituminous coal	Georgia
AD-570	Fly Ash F	Bituminous coal	Kentucky
AD-517	Fly Ash F	Bituminous coal	Michigan
AD-536, -536(2), -536(3), -536(4)	Silica fume	Silicon metal	Alabama
AD-549	Silica fume	Ferro-silicon	Alabama
AD-557	Silica fume	Ferro-silicon	Alabama
AD-548	Silica fume	Ferro-silicon	Kentucky
AD-552	Silica fume	Ferro-silica	New York
AD-553	Silica fume	Ferro-chrome	New York
AD-550	Silica fume	Mixed fume from chromium, magnesium, and ferro-silicon	Ohio
AD-551	Silica fume	Silicon metal	Ohio
AD-541	Silica fume	Silicon metal	Ohio
AD-542	Silica fume	Ferro-silicon	Ohio
AD-543	Silica fume	Ferro-silicon	Ohio
AD-545	Silica fume	Ferro-silicon and manganese-silicon	Tennessee

** Used with fly ash AD-577 to make RC-807.

+ Santorin earth.

Source	Class	Produced from	Source
AD-544 (Si 75)	Silica fume	Ferro-silicon 75	Washington
AD-544 (Si 98)	Silica fume	Ferro-silicon 98	Washington
AD-558	Silica fume	Ferro-silicon	Washington
AD-546	Silica fume	Ferro-silicon	West Virginia
		Slag	
AD-537††	Blast-furnace slag	--	Michigan

†† Used in RC-758.

PART III: TESTS AND PROCEDURES

5. In addition to characterization tests, tests were made on combinations of these materials, as pastes and mortars. Special procedures as described below were required for the tests on silica fume and preparation of paste specimens for creep tests.

Physical Tests

Compressive strength of mortars

6. The compressive strength of mortars made from the cements and admixtures was determined generally using the procedures in American Society for Testing and Materials (ASTM) C 109. Mortars were proportioned using 1 part cement to 2.75 parts graded standard sand, except for the mixtures of pozzolans or silica fumes and portland cement which were proportioned so that 30 and 60 percent of the portland cement, respectively, was replaced by an equal absolute volume of pozzolan or silica fume, while the amount of sand in the mortar remained unchanged from that amount used in the portland cement mortars.

7. The portland cement mortars were made using a water-cement ratio of 0.485, as specified in ASTM C 109, and the flow measured on those two portland cements (RC-688 and RC-705) used in the pozzolanic materials portion of this work. The average of the flow measurements on these two portland cements was used as the control flow for the portland cement-pozzolan blends. The water-cement ratio of the mixtures is shown on each pozzolan test report.

8. Blended-cement mortars were made as specified in ASTM C 109 where the water-cement ratio used is that required to produce a flow of 110 $\pm$ 5 percent. Compressive strength, flow, and water-cement ratio data for blended cements are shown on each blended cement test report.

9. Mortars made using mixtures of 30 and 60 percent replacement of portland cement with silica fume were found to be too dry and difficult to work when mixed at a 0.485 water-cement ratio; therefore, the water-cement ratio was increased to achieve a flow of 110 $\pm$ 5 percent. The flow of 110 + 5 percent was not achieved since at the higher water-cement ratios the mortars became very fluffy, soft, and sticky which made the mortar displace and adhere to the tamper upon tamping the mortar into the cube mold. Since the mortar could not be properly compacted in the mold and finished, the water-cement

ratio was adjusted until a workable mixture was achieved and then the flow was measured. The water-cement ratios ranged from 0.511 to 0.782 as shown on the test reports for silica fumes.

10. All compressive strength specimens were moist cured under conditions complying with ASTM C 511 for 24 hr prior to demolding, except for those specimens made using mortars where 60 percent of the portland cement was replaced by a pozzolan. These specimens were demolded after 48 hr since they were too soft to demold at 24 hr. After demolding, all specimens were identified and placed in quart* glass jars with two cubes per jar and each jar filled to capacity with lime water, sealed, and further identified on the outside. These jars were then stored in a moist atmosphere at 23° C until date of test.

11. Compressive strength was determined at ages 3, 7, 28, 56, 90, 180 days, and 1 yr. The results of the compressive strength tests are shown on each test report for the test material, i.e., portland cement, blended cements, pozzolans include 30 and 60 percent replacement of cement test data for pozzolans including silica fumes.

Pozzolanic activity index

12. The procedure in ASTM 311 was used to determine the pozzolanic activity index with portland cement of pozzolans.

13. All pozzolans were tested for strength of lime-pozzolan mortar by weighing and mixing one part of hydrated calcium hydroxide and nine parts of graded standard sand with sufficient water to produce a flow of 110 ± 5 percent. Three 2-in. cubes were molded from each test mixture. Mortar mixing, flow test, and cube molding were performed in accordance with ASTM C 109. After each set of three cubes was molded and cut off, the mold was covered and placed in the moist cabinet at 23° C for 24 hr. At 24 hr of age, the mold was sealed with microcrystalline wax, inverted, and placed in a forced draft oven at 55° C for 6 days. On the seventh day after molding, the cube molds were removed from the oven and allowed to cool to room temperature. The cubes were then demolded and tested for compressive strength.

14. The lime-silica fume mortars were adjusted as was done with the portland cement-silica fume mixtures to obtain a workable mixture.

15. The compressive strength, water-cement ratio, and flow values are shown on each test report for that pozzolan.

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* A table of factors for converting non-SI to SI (metric) units is presented on page 3.

Compressive strength of pozzolans tested without portland cement

16. All fly ash samples were used in mortars from which 2-in. cubes were tested for compressive strength at 3, 7, and 28 days. The mortar mixtures were proportioned using one part fly ash to three parts graded standard sand and sufficient water to produce a flow of 110 $\pm$ 5 percent. The mixing, flow, and casting procedures were all in accordance with ASTM C 109. The cubes were cured for 3 days in the molds in a moist atmosphere at 23° C before demolding and testing for compressive strength at 3 days. The remainder of the cubes were stored in lime water at 23° C until date of test. The compressive strength test results, flow test data, and water-cement ratios are shown in the test reports for pozzolans. AD-506 showed some strength at 3 days and fell apart by 7 days; as a result, testing was discontinued. AD-507 and AD-509 did not show sufficient strength to demold the cubes at 3 or 7 days. Further testing was discontinued. AD-510 was cementitious as indicated by the compressive strengths at 3, 7, and 28 days. AD-512 was cementitious; however, there was a loss in compressive strength from 3 to 7 days. Cubes expanded from 2 in. to 2-1/32 in. and showed some cracking by day 7. Tests were discontinued at 7 days. AD-513 was cementitious as indicated by the 3-, 7-, and 28-day compressive strength data.

Soundness and time of setting

17. Autoclave expansion and time-of-setting tests were performed on normal-consistency pastes of portland cement and of blended cements. The normal-consistency pastes were proportioned, mixed, and tested in accordance with ASTM C 187.

18. From the normal-consistency paste, autoclave specimens were molded, cured, and tested in accordance with ASTM C 151. The autoclave-expansion test was performed on portland and on blended-cement pastes, and on 20 percent mixtures of pozzolans and portland cement.

19. Time of setting of blended cements was determined by mixing a paste of normal consistency and testing for initial and final time of setting according to ASTM C 191.

20. Time of setting of portland cement was determined by using the normal consistency paste to form the test specimen and checking every 10 min for initial or final set using the procedures of ASTM C 266.

Air content of mortar

21. Both the portland and blended cements were tested for air content in accordance with ASTM C 185.

Density

22. The density of portland cement was assumed to be 3.15 Mg/m^3 and the air content calculated while the density of blended cements was determined using the procedure in ASTM C 188 and the air content calculated using that density.

23. The density of all blended cements and pozzolans was determined by ASTM C 188. All density determinations were made using kerosine.

Length change on drying or soaking

24. The drying shrinkage and expansion in lime-water test specimens were prepared from mortars composed of the same materials in the same proportions as those mortars for determining compressive strength of portland cements, blended cements, and mixtures of pozzolans and portland cement. RC-688 and RC-705 were used as the control cements.

25. Specimen size, molding procedures, and mortar preparation were as prescribed in ASTM C 157, except the specimen initial curing period was extended from 24 hr to 48 hr and to 72 hr for those mortar mixtures where 60 percent of the portland cement was replaced by solid volume with a pozzolan. The extended curing period was necessary due to the slow strength gain of some blends of portland cement and pozzolans. After demolding and initial length measurement, the prisms were returned to the saturated lime water for additional curing to 28 days and measured again.

26. Six 1- by 1- by 11-1/4-in. prisms were molded from each mortar mixture and the inserts set for a 10-in. gage length in each prism. After the initial 28-day curing period, each set of six prisms was divided into two groups of three randomly selected prisms each. One group was tested for drying shrinkage in air storage and the other group tested for length change during lime-water storage. Measurements were made at 56, 180, and 365 days, with some measurements being made at later ages.

27. The initial curing period just after molding was accomplished in an atmosphere maintained at 23° C and 95 to 100 percent relative humidity according to ASTM C 109.

28. Additional curing of all prisms up to 28 days of age was accomplished in lime-saturated water and those prisms tested for length change in lime-water storage were returned to the saturated lime water maintained at 23° C.

29. The prisms tested for drying shrinkage were stored in an atmosphere maintained at 23° C and a relative humidity of 50 ± 4 percent. These prisms were stored on heavy nonreactive wire mesh so that all sides of the prisms were exposed to free air movement.

Fineness

30. The fineness of portland cements, shown on each portland cement test report, and the fineness of blended cements, as shown on the test reports of blended cements, was determined using the test procedures and apparatus specified in ASTM C 204.

31. The fineness of pozzolans shown in test reports on pozzolans was determined using the test procedures and apparatus specified in ASTM C 311. For the silica-fume pozzolans the test procedures were modified as follows. Porosity is defined in ASTM C 204 as the ratio of volume of voids in a bed of material to the total or bulk volume of the bed. Air-permeability fineness is fairly accurate as long as the porosity of the test material is near that of the National Bureau of Standards Standard Reference Material (SRM) 114 used to calibrate the air-permeability apparatus. Silica fume was weighed and tried until a sample mass was found that could be compacted as required in the test method. If the compactive effort was judged to be near that of the SRM without rebound, a test was completed. In the process, it was found that fineness determinations could be made over a range of weighed amount of silica fume and for each porosity calculated there was a fineness that did not agree with fineness at other porosities on the same sample. This indicated that fineness was dependent on porosity so a linear correlation coefficient was calculated for each set of data for each sample using porosity as one variable and fineness as the second variable. The correlation coefficient indicated the variables were related and could be expressed as a straight line. From this the fineness of the silica fumes was extrapolated, by linear regression, to a porosity of 0.500, as shown in Table 1, so that the fineness of silica fumes could be compared to that of the SRM.

32. Since this work was done, ASTM C 204 has been revised to include a method for calculating the fineness of materials other than portland cement.

Table 2 is a recalculation of fineness of materials in Table 1 using the original measurements for fineness to calculate the fineness of each by the method described in the Appendix of ASTM C 204.

33. The correlation coefficients listed in Table 2 indicate that the closer the correlation coefficient is to one, the better the agreement between fineness determined at each porosity on the same material.

Creep

34. Two-inch cubes and 3- by 6-in. cylinders were made for creep studies. These specimens were cast from pastes of portland cement, blended cements, and mixtures of portland cement and pozzolans using water-cement or water-cement plus pozzolan ratios ranging from 0.25 to 0.60. The intent was to cast specimens from pastes that would not bleed or subside; however, some bleeding and subsidence occurred. The combinations of materials used and starting test ages for 17 paste mixtures are given in Appendix A. Comparison of creep data for different mixtures provides opportunity to study the effect of different cements or different fly ash admixtures or different amounts of one admixture or water content or test age or combinations of these on creep of paste.

35. Paste preparation. The preparation of the pastes began with the mixing of portland cement using a water-cement ratio (w/c) of 0.60. Several mixing procedures were tried using a small quantity of prehydrated cement in a kitchen blender and later a variable-speed laboratory-size pigment disperser. Both methods resulted in mixtures that bled and subsided. Fillers, such as bentonite, were discussed and found to be unacceptable since they were pozzolanic in the presence of a hydrating portland cement.

36. Since previous trials failed to produce desirable results, it was apparent a cement was needed that would set fast to hold the cement particles in suspension and still be workable enough to fill the molds without voids and yet plastic enough to be trowel finished. False-setting cement appeared to be worth trying. About 30 lb of portland cement (RC-688(3)) were placed in an oven set at approximately 80° C (180° F) for at least 72 hr prior to use. The intent was to dehydrate the gypsum in the portland cement to hemihydrate so that false set would occur when mixed with water.

37. A paste was prepared using w/c of 0.60 using hot water and hot cement directly from the oven. The mixing procedure was that described in ASTM C 451 using a mixer that met the requirements of ASTM C 305. Casting of

the trial specimens followed immediately after mixing and within the time period described in ASTM C 451 from mixer to initial penetration of the false-set paste. This mixture did show false set and specimens cast from it were cured in a moist cabinet meeting the requirements of ASTM C 511 until the specimens showed the cement was beginning to show initial set. At this point the specimens were vibrated on a vibrating table, using a low amplitude, to return some plasticity to the paste so that the specimens could be cut off and trowel finished. The specimens prepared using the false-setting cement indicated the procedures used would produce the desired results. Sixty percent by volume of the portland cement was replaced with a pozzolan (AD-510) and mixed by the false-set procedure using w/c of 0.60 and produced satisfactory results, also.

38. Compressive strength specimens. Two-inch cube specimens were cast from each of the test mixtures. Cubes cast from mixtures where the w/c was 0.60 or 0.40 were poured and spaded with a spatula to eliminate air voids and placed immediately in the moist cabinet to develop the first indication of initial set before being vibrated to return plasticity to the mixture so that the specimens could be cut off and troweled. The cube molds were returned to the moist cabinet and the specimens moist cured in the molds until the initial test age at which time all cubes were demolded. Those cubes not tested were placed in lime water for future testing. Each cube was measured prior to testing for the purpose of determining subsidence and to calculate compressive strength. Compressive strength was used to approximate the strength level and age at which to initiate creep testing.

39. Creep specimens. Waxed stiff cardboard cylinder molds (3 by 6-1/2 in.) were instrumented with strain gages and fitted with a 1- by 3-in. collar taped in place to tie it to the mold and sealed against water loss. The molds were filled with the test mixture, covered with a glass plate, and stored in the moist cabinet until the cement began to show initial set or was plastic enough to be workable. At this point the cylinder molds were removed from the moist cabinet and checked for bleed water by pouring the free water on top into a graduated cylinder for measurement. The mold was then vibrated at low amplitude to return plasticity to the mixture. The collar was removed and the top cut off and trowel finished. After troweling, the cylinders were returned to the moist cabinet until 24 hr prior to creep loading. Pastes made using the 0.60 w/c showed bleeding and subsidence. The bleed water was measured and the w/c recalculated based on the water remaining in the mixture. The recalculated

w/c for the cement paste was 0.56 and for the cement-pozzolan paste 0.58. The specimens cast from mixtures using a 0.25 w/c were molded by pressing and vibrating the paste in the mold and around the strain gage and supports, trowel finished on top, and moist cured until 24 hr before initiation of creep test.

40. At 24 hr before creep specimen loading, the cylinder molds were stripped from the creep specimens and mounted in a surfacing machine. The top and bottom of each specimen was ground to plane parallel surfaces perpendicular to the long axis of the cylinder. Each cylinder was ground to 6 in. in length so that all cylinders in the creep test rig would measure 3 in. by 6 in.

Chemical Tests

Cements and blends

41. Chemical analysis and tests for heat of hydration were performed on a series of portland cements and cement blends. The portland cements and blended cements were analyzed for composition, reported as SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, SO_3, Na_2O, K_2O, TiO_2, Mn_2O_3, P_2O_5, insoluble residue, and loss on ignition. Acid-soluble and water-soluble alkalies were determined. Heats of hydration at 7 and 28 days were determined on 3 portland cements and 12 commercially blended cements. Three of these blends contained slag and nine contained pozzolans. The methods of analysis are listed below, and some are described in Appendix E.

Portland Cements

Components	Methods: Primary	Methods: Secondary
SiO_2	ASTM C 114, NH_4Cl, gravimetric	Double evaporation, gravimetric
Al_2O_3	ASTM C 114, ammonium hydroxide group ($R_2O_3 - Fe_2O_3 = Al_2O_3$)	Acid filtrate from SiO_2, atomic absorption (AA)
Fe_2O_3	ASTM C 114	As above
CaO	ASTM C 114, gravimetric	Acid filtrate, EDTA, titration
MgO	ASTM C 114, gravimetric	Acid filtrate
SO_3	ASTM C 114, gravimetric	--
Loss on ignition	ASTM C 114, gravimetric	--
Insoluble residue	ASTM C 114, gravimetric	--
Acid-soluble alkalies	ASTM C 114, AA	--
Water-soluble alkalies	ASTM C 114, AA	--

Components	Methods — Primary	Methods — Secondary
TiO_2	ASTM C 114, solution used from acid-soluble alkali, AA	–
P_2O_5	ASTM C 114, colorimeter	--
Mn_2O_3	ASTM C 114, acid filtrate from SiO_2, AA	
Heat of hydration	ASTM C 186	ASTM C 186-49 (Federal Method 1301.1 - 1960, alternate method, paragraph 5-6)

Blends

Components	Methods — Primary	Methods — Secondary
SiO_2	ASTM C 595, gravimetric	$LiBO_2$ fusion, AA
Al_2O_3	ASTM C 595, gravimetric differences	$LiBO_2$ fusion, AA
Fe_2O_3	ASTM C 595, titration	$LiBO_2$ fusion, AA
CaO	ASTM C 595, gravimetric	$LiBO_2$ fusion, EDTA, titration
SO_3	ASTM C 595, gravimetric	--
Loss on ignition	ASTM C 595, gravimetric	--
Acid-soluble alkali	ASTM C 114, AA	--
Water-soluble alkali	ASTM C 114, AA	--
TiO_2	$LiBO_2$ fusion, AA	--
P_2O_3	$LiBO_2$ fusion, plasma emission (PE)	--
Mn_2O_3	$LiBO_2$ fusion, AA	--
Heat of hydration	ASTM C 186-49 (Federal Method 1301.1 - 1960, the alternate method for blended cements, paragraph 5-7)	

Pozzolans and slag

42. Pozzolans and slag were analyzed, and the results were expressed as oxides. Alkalies were determined as water-soluble, available, acid-soluble, and total. Only acid-soluble alkalies were determined in slags. Other analyses were for moisture loss and loss on ignition. All these materials were analyzed by ASTM methods except for total alkali, iron, and secondary check methods for SiO_2, Al_2O_3, and MgO. The total alkalies and secondary methods consisted of fusing the sample with $LiBO_2$, followed by dissolving the fusion in hydrochloric acid and analyzing the solution by the use of atomic absorption spectroscopy (AA). The methods used for analysis are listed below:

Fly Ashes, Natural Pozzolans, and Slag

Components	Methods: Primary	Methods: Secondary
SiO_2 (except slag)	ASTM C 311, gravimetric	$LiBO_2$ fusion, AA
Slag	ASTM C 114, gravimetric	
Al_2O_3	ASTM C 114, gravimetric, ammonium hydroxide group ($R_2O_3 - Fe_2O_3 = Al_2O_3$)	$LiBO_2$ fusion, AA
Fe_2O_3	ASTM C 114, $LiBO_2$ titration	$LiBO_2$ fusion, AA; ASTM C 595, titration
CaO	ASTM C 114, gravimetric	$LiBO_2$ fusion, AA EDTA, titration
MgO	ASTM C 114, gravimetric	$LiBO_2$ fusion, AA
SO_3	ASTM C 114, gravimetric	--
Moisture loss	ASTM C 311, gravimetric	--
Loss on ignition (slag)	ASTM C 114, gravimetric	--
Loss on ignition (others)	ASTM C 311, gravimetric	--
Total alkalies	$LiBO_2$ fusion, AA	--
Acid-soluble alkalies	ASTM C 114, AA	--
Water-soluble alkalies	ASTM C 114, AA	--

43. Heat-of-hydration values were determined by replacing 30 percent and 60 percent of a Type I and Type II cement with pozzolan by solid volume and measured at 7 and 28 days by the heat of solution.

Silica fume

44. There were 19 silica fumes from 16 sources analyzed chemically. One, AD-536, was blended with portland cements for the determination of heat of hydration. The data are in Tables 3 and 4. The various types of fumes, chemical, and physical properties, are determined by the type of furnace, burden in the furnace, and fuel used. The silica fumes were analyzed for the elements present and results were reported both as oxides and elements. Those elements determined were Si, Al, Fe, Ca, Mg, S, Na, K, Mn, Cr, and Cl. Moisture loss and loss on ignition were also determined. The method of AA analysis is in Appendix E. The iron method described in ASTM C 595 was erratic in results and in AD-557 failed to detect 98 percent of the iron present. As a result, a new method for fumes and pozzolanic material was developed and is in Appendix E. No direct method was used to determine carbon content in the silica fumes but the assumption is that carbonates are included in the loss of ignition. Methods of analysis are shown on the following page.

Silica Fumes

Component	Methods: Primary	Methods: Secondary
SiO_2	ASTM C 311, gravimetric	$LiBO_2$ fusion, AA
Al_2O_3	ASTM C 311, gravimetric, ammonium hydroxide group (R_2O_3 - Fe_2O_3 = Al_2O_3)	$LiBO_2$ fusion AA
Fe_2O_3	ASTM C 114, $LiBO_2$ fusion, titration	$LiBO_2$ fusion, AA
CaO	ASTM C 311, gravimetric	$LiBO_2$ fusion, AA
MgO	ASTM C 311, gravimetric	$LiBO_2$ fusion, AA
SO_3	ASTM C 311, gravimetric	--
Chloride (Cl)	Electric-tetrametric	--
Cr_2O_3	$LiBO_2$ fusion, emission argon plasma (EAP)	--
Mn_2O_3	$LiBO_2$ fusion, AA	--
Moisture loss	ASTM C 311, gravimetric	--
Loss on ignition	ASTM C 311, gravimetric	--
Total alkali	$LiBO_2$ fusion, AA	--
Acid-soluble alkali	ASTM C 114, AA	--
Available alkali	ASTM C 311, AA	--

45. The acceptance test requirements for pozzolans require chemical analysis for sum of percentages of SiO_2, Al_2O_3, and Fe_2O_3 but do not require the individual values. A value for Al_2O_3 plus Fe_2O_3 is obtained based on a sodium-carbonate fusion. This is, however, not a convenient procedure to use if one wants Al_2O_3 and Fe_2O_3 individually. An attempt was made to use a procedure involving dissolution in mixed acids then given in ASTM C 595, but the results were not satisfactory. Hence, a procedure based on a lithium borate fusion was adopted and used successfully; see Appendix E.

Petrographic Examination

46. The procedures used in the petrographic examinations are given in Appendices B C, and D.

PART IV: RESULTS

Physical Tests

47. Tables 1 and 2 show fineness data for the silica fumes calculated by extrapolation to porosity (e) of 0.500 and by the method given in the Appendix of ASTM C 204. In most cases the agreement between the two methods is satisfactory. When this work was done, the ASTM method was not available.

48. Tables 3 and 4 show length-change data (drying-shrinkage, expansion) for cements RC-688 and RC-688(3) and RC-705, respectively, with nine fly ashes, seven silica fumes, and one natural pozzolan at 30 or 60 percent replacement levels or both.

49. The report of the creep testing of cement pastes is included as Appendix A.

Chemical Tests

Cements

50. Tables 5 through 8 show various cement parameters compared by chemical analyses; these parameters are: use and nonuse of preheater (Table 5), use of preheater, different plants (Table 6), use and nonuse of slag (Table 7), and use and nonuse of pozzolan (Table 8). Results of heat-of-hydration tests of blended cements are given in Table 9.

Pozzolans and slag

51. Tables 10 and 11 show data for heat of hydration, relation of heat of hydration to CaO by chemical analysis and surface area, and chemical data for these materials. Fly ashes with high CaO by chemical analysis such as AD-510 and AD-513 reduce the heat of hydration very little, if any, when compared to the cements at 7 days and 30 percent replacement. AD-513 at 30 percent replacement was essentially the same as Type I cement at 7 days. Class N pozzolans such as volcanic ashes and silica fumes usually contained over 50 percent SiO_2 (Table 12). When silica fume AD-536 was combined with cements RC-688 and RC-705, heats of hydration were reduced about 12 and 7 cal/g at 7 days and 6 and 5 cal/g at 28 days, respectively. Newman and Wells* discuss undissolved residues

* Newman, E. S. and Wells, L. S. 1952. "Heat of Hydration and Pozzolan Content of Portland-Pozzolan Cements," Journal of Research of Bureau of Standards, Vol 49, No. 2, Research Paper 2342, pp 57-60.

of cement-pozzolan mixtures from heat of solution. They conclude that the rate of solution will vary with the surface area and with the type of pozzolan, and that a curve must be determined for each variety of pozzolan and of cement. They did determine the percent pozzolan, but they did not give an analysis of the residue. A comparison is made in Table 11 of the relationship of various percentages of calcium of different pozzolans and their fineness. This comparison was made by comparing the heat of hydration at 7 days of 30 percent replacement by volume with various pozzolans of a Type I cement and a Type II, moderate-heat cement. The fineness of the pozzolans varied from 12,800 to 6,870 cm^2/cc in these blends and showed no relationship to heat of hydration when compared to the quantity of lime in these pozzolans. The multiple regression factor for the varying quantity of lime was for Type I cement blends, 89.98 percent; and for Type II, moderate-heat cement blends, 74.98 percent.

52. Chemical data, expressed as oxides, are shown in Table 13. They show:

a. A range in SiO_2 from 43 percent (AD-545) to 97 percent (AD-536(3)) with 11 of the 16 different fumes containing more than 80 percent SiO_2.

b. A large amount, 23 percent, of Mn_2O_3 in AD-545 with a low SiO_2 content of 43 percent and significant amounts of Al_2O_3, Fe_2O_3, CaO, MgO, and alkalies.

c. High iron contents for fumes AD-546, 549, and 557 (14, 11, and 15 percent, respectively).

d. Twelve and ten percent MgO in AD-550 and AD-553, respectively.

e. Especially high K_2O (7 percent) in AD-545.

f. Over 4 percent chloride in AD-550.

g. Loss on ignition of 12, 14, and 11 percent in AD-544(98), AD-549, and AD-557, respectively.

53. The same basic data, expressed as elements, are shown in Table 14.

Physical and Chemical Tests

54. The test reports for each of the materials (59 cements, 11 fly ashes, 3 natural pozzolans, 1 slag, and 19 fumes from 16 sources) are included in Appendix F; some reports include tests on more than one sample.

Petrographic Examinations

55. Results of the petrographic examinations are presented in Appendices B, C, and D.

PART V: DISCUSSION

56. Since so many different materials (cements, pozzolans, and slag) and types of data (physical, chemical, and petrographic) are presented in this report, it was impractical to present a detailed discussion. Instead, the data are presented for such use as may be desired.

57. Some discussion is included in Appendices A, B, C, and D and is not repeated here.

PART VI: CONCLUSION

58. The use of energy conservation measures such as precalciners or preheaters in producing portland-cement clinker did not have any significant effect on physical or chemical properties or constitution of the cement as revealed by petrographic examination as compared with samples not produced with such equipment.

REFERENCES

American Society for Testing and Materials (ASTM), 1985 Annual Book of ASTM Standards, Section 4, Vol 04.01, "Cement, Lime, Gypsum," and Section 4, Vol 04.02, "Concrete and Mineral Aggregates," Philadelphia, Pa.

C 109, "Standard Test Method for Compressive Strength Hydraulic Cement Mortars (Using 2-in. or 50-mm Cube Specimens)."

C 114, "Standard Methods for Chemical Analysis of Hydraulic Cement."

C 151, "Standard Test Method for Autoclave Expansion of Portland Cement."

C 157, "Standard Test Method for Length Change of Hardened Cement Mortar and Concrete."

C 186, "Standard Test Method for Heat of Hydration of Hydraulic Cement."

C 187, "Standard Test Method for Normal Consistency of Hydraulic Cement."

C 188, "Standard Test Method for Density of Hydraulic Cement."

C 191, "Standard Test Method for Time of Setting of Hydraulic Cement by Vicat Needle."

C 204, "Standard Test Method for Fineness of Portland Cement by Air Permeability Apparatus."

C 266, "Standard Test Method for Time of Setting of Hydraulic Cement by Gillmore Needles."

C 305, "Standard Method for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency."

C 311, "Standard Methods of Sampling and Testing Fly Ash or Natural Pozzolans for Use as a Mineral Admixture in Portland Cement Concrete."

C 451, "Standard Test Method for Early Stiffening of Portland Cement (Paste Method)."

C 511, "Standard Specification for Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes."

C 595, "Standard Specifications for Blended Hydraulic Cements."

US Army Engineer Waterways Experiment Station. 1949 (Aug). "Handbook for Concrete and Cement" (with quarterly supplements), Vicksburg, Miss.

References for the Appendices are listed in each Appendix or identified in footnotes.

Table 1

Air-Permeability Fineness for 15 Silica-Fume Samples Extrapolated to Porosity 0.500

	Round No. 1			Round No. 2			Round No. 3			Linear Correlation Coefficient	Fineness by Extrapolation to e = 0.500	
AD No.	e*	cm^2/cc	m^2/kg	e*	cm^2/cc	m^2/kg	e*	cm^2/cc	m^2/kg	r	cm^2/cc	m^2/kg
536	0.714	58,700	2640	0.738	39,340	1770	0.753	25,740	1160	1.00	239,000	10,700
536(2)	0.714	98,900	4450	0.738	82,230	3700	0.753	65,160	2940	0.99	286,000	12,800
541	0.727	61,740	2790	0.740	46,980	2130	0.752	34,050	1540	1.00	313,000	14,100
542	0.762	85,150	3700	0.795	57,400	2500	0.821	38,990	1700	1.00	291,000	12,600
543	0.779	75,150	3370	0.803	54,050	2420	0.816	42,360	1900	1.00	322,000	14,500
544(75)	0.796	63,150	2770	0.808	60,580	2660	0.844	58,520	2570	0.94	92,000	4,000
544(98)	0.819	113,720	5190	0.825	105,320	4810	0.839	88,310	4030	1.00	516,000	23,600
548+	0.699	35,230	1490	0.711	27,680	1170	0.723	20,430	860	1.00	158,000	6,700
549+	0.793	45,510	2020	0.798	44,240	1970	0.805	42,470	1890	1.00	111,000	4,900
550	0.782	39,600	1680	0.786	35,050	1480	0.791	32,150	1360	0.98	278,000	12,000
551	0.842	163,050	7250	0.878	148,930	6620	0.890	97,860	4350	0.83	**	**
552	0.811	74,650	3350	0.816	67,750	3040	0.840	42,380	1900	1.00	415,000	18,700
553	0.821	55,420	2480	0.823	53,810	2410	0.827	49,290	2210	1.00	391,000	17,300
557	0.840	142,550	5750	0.845	136,460	5500	0.856	129,680	5230	0.98	414,000	16,700
558	0.825	98,800	4390	0.827	97,300	4320	0.830	92,000	4090	0.98	570,000	25,000

* e = porosity.
** Not determined.
+ Partial round No. 4.

	Round 4		
	e	cm^2/cc	m^2/kg
AD-548	0.727	17,840	750
AD-549	0.830	37,180	1650

Table 2

Fineness Values for Silica Fume Recalculated

According to ASTM C 204

AD No.	Surface Area cm^2/g	Surface Area m^2/kg	Correlation Coefficient r
536	96,260	9,630	1.0000
	95,900	9,590	
	96,560	9,660	
	Avg	9,630	
536(2)	108,460	10,850	0.9974
	111,780	11,180	
	107,130	10,710	
	Avg	10,910	
541	120,770	12,080	0.9997
	120,380	12,040	
	118,770	11,880	
	Avg	12,000	
542	80,390	8,040	0.9955
	84,090	8,410	
	74,440	7,440	
	Avg	7,960	
543	84,440	8,440	0.9993
	86,300	8,630	
	87,280	8,730	
	Avg	8,600	
544(75)	51,050	5,100	0.9632
	70,960	7,100	
	52,480	5,250	
	Avg	5,820	
544(98)	112,500	11,250	0.9986
	115,000	11,500	
	116,720	11,670	
	Avg	11,470	
548	68,940	6,890	1.0000
	68,880	6,890	
	69,000	6,900	
	Avg	6,890	
549	425,500	42,550	0.8984
	85,950	8,510	
	131,090	13,110	
	Avg	21,390	
550	72,730	7,270	0.9831
	69,860	6,990	
	72,750	7,280	
	Avg	7,180	

(Continued)

Table 2 (Concluded)

AD No.	Surface Area cm^2/g	Surface Area m^2/kg	Correlation Coefficient r
551	101,450	10,140	0.9637
	118,250	11,820	
	89,650	8,960	
	Avg	10,310	
552	87,870	8,790	0.9987
	89,880	8,990	
	90,510	9,050	
	Avg	8,940	
553	81,910	8,190	0.9995
	82,190	8,220	
	81,820	8,180	
	Avg	8,200	
557	435,020	43,500	0.9842
	274,380	27,430	
	247,240	24,720	
	Avg	31,880	
558	112,110	11,210	0.9936
	113,290	11,330	
	112,230	11,220	
	Avg	11,250	

Table 3

Drying Shrinkage and Lime-Water Expansion of 1- by 1- by 11-3/4 in. Prisms Made with Cement RC-688 and Different Pozzolans, Length Change, Percent

RC=RC688 AD= PCT_REPL=.

OBS	TIME	DRY	WET
1	28	0.005	0.004
2	56	-0.083	0.010
3	90	-0.093	0.011
4	180	-0.102	0.015
5	365	-0.107	0.025

RC=RC688 AD=AD505 PCT_REPL=30

OBS	TIME	DRY	WET
6	28	0.005	0.005
7	56	-0.079	0.010
8	90	-0.093	0.012
9	180	-0.102	0.017
10	406	-0.102	0.030

RC=RC688 AD=AD505 PCT_REPL=60

OBS	TIME	DRY	WET
11	28	0.006	0.005
12	56	-0.063	0.014
13	90	-0.071	0.016
14	180	-0.106	0.027
15	365	-0.103	0.042

RC=RC688 AD=AD506 PCT_REPL=30

OBS	TIME	DRY	WET
16	28	0.007	0.007
17	56	-0.082	0.012
18	90	-0.096	0.014
19	180	-0.105	0.018
20	406	-0.104	0.029

RC=RC688 AD=AD506 PCT_REPL=60

OBS	TIME	DRY	WET
21	28	0.010	0.009
22	56	-0.070	0.018
23	90	-0.077	0.021
24	180	-0.087	0.032
25	365	-0.087	0.048

RC=RC688 AD=AD507 PCT_REPL=30

OBS	TIME	DRY	WET
26	28	0.006	0.008
27	56	-0.087	0.009
28	90	-0.096	0.010
29	180	-0.101	0.013
30	384	-0.105	0.024

RC=RC688 AD=AD507 PCT_REPL=60

OBS	TIME	DRY	WET
31	28	0.008	0.008
32	56	-0.076	0.010
33	90	-0.088	0.012
34	180	-0.100	0.019
35	365	-0.098	0.030

(Continued)

(Sheet 1 of 5)

Table 3 (Continued)

RC=RC688 AD=AD509 PCT_REPL=30

OBS	TIME	DRY	WET
36	28	0.007	0.008
37	56	-0.083	0.009
38	90	-0.092	0.011
39	180	-0.098	0.015
40	384	-0.098	0.026

RC=RC688 AD=AD509 PCT_REPL=60

OBS	TIME	DRY	WET
41	28	0.008	0.008
42	56	-0.072	0.011
43	90	-0.085	0.013
44	180	-0.097	0.022
45	365	-0.097	0.036

RC=RC688 AD=AD510 PCT_REPL=30

OBS	TIME	DRY	WET
46	28	0.018	0.018
47	56	-0.080	0.020
48	90	-0.092	0.023
49	180	-0.101	0.027
50	384	-0.099	0.041

RC=RC688 AD=AD510 PCT_REPL=60

OBS	TIME	DRY	WET
51	28	0.026	0.026
52	56	-0.055	0.030
53	90	-0.083	0.033
54	180	-0.095	0.044
55	365	-0.105	0.058

RC=RC688 AD=AD511 PCT_REPL=30

OBS	TIME	DRY	WET
56	28	0.003	0.003
57	56	-0.095	0.005
58	90	-0.097	0.008
59	180	-0.103	0.015
60	365	-0.114	0.022

RC=RC688 AD=AD511 PCT_REPL=60

OBS	TIME	DRY	WET
61	28	0.012	0.012
62	56	-0.079	0.013
63	90	-0.089	0.016
64	180	-0.097	0.023
65	365	-0.095	0.038

RC=RC688 AD=AD512 PCT_REPL=30

OBS	TIME	DRY	WET
66	28	0.010	0.010
67	56	-0.084	0.012
68	90	-0.090	0.015
69	180	-0.093	0.021
70	365	-0.103	0.030

RC=RC688 AD=AD512 PCT_REPL=60

OBS	TIME	DRY	WET
71	28	0.021	0.022
72	56	-0.047	0.026
73	90	-0.055	0.032
74	180	-0.064	0.041
75	365	-0.067	0.059

(Continued)

(Sheet 2 of 5)

Table 3 (Continued)

RC=RC688 AD=AD513 PCT_REPL=30

OBS	TIME	DRY	WET
76	28	0.005	0.005
77	56	-0.108	0.007
78	90	-0.111	0.009
79	180	-0.115	0.016
80	365	-0.126	0.024

RC=RC688 AD=AD513 PCT_REPL=60

OBS	TIME	DRY	WET
81	28	0.011	0.011
82	56	-0.052	0.020
83	90	-0.059	0.028
84	180	-0.071	0.039
85	365	-0.076	0.054

RC=RC688 AD=AD518 PCT_REPL=30

OBS	TIME	DRY	WET
86	28	0.007	0.007
87	56	-0.104	0.010
88	90	-0.115	0.013
89	180	-0.121	0.019
90	365	-0.133	0.025

RC=RC688 AD=AD518 PCT_REPL= [illegible]

OBS	TIME	DRY	WET
91	28	0.015	0.013
92	56	-0.128	0.018
93	90	-0.154	0.017
94	180	-0.167	0.019
95	406	-0.172	0.028

RC=RC688 AD=AD536 PCT_REPL=30

OBS	TIME	DRY	WET
96	28	0.012	0.012
97	56	-0.136	0.016
98	90	-0.162	0.018
99	180	-0.183	0.024
100	365	-0.204	0.030

RC=RC688 AD=AD536 PCT_REPL=60

OBS	TIME	DRY	WET
101	28	0.031	0.032
102	56	-0.202	0.036
103	90	-0.227	0.037
104	180	-0.243	0.047
105	365	-0.248	0.055

RC=RC688 AD=AD541 PCT_REPL=30

OBS	TIME	DRY	WET
106	28	0.021	0.025
107	56	-0.134	0.028
108	90	-0.150	0.031
109	180	-0.184	0.037
110	365	-0.210	0.044

RC=RC688 AD=AD541 PCT_REPL=60

OBS	TIME	DRY	WET
111	28	0.034	0.034
112	56	-0.088	0.036
113	90	-0.108	0.040
114	180	-0.128	0.048
115	365	-0.132	0.051

(Continued)

Table 3 (Continued)

RC=RC688(3) AD=AD536(2) PCT_REPL=30

OBS	TIME	DRY	WET
121	28	-0.104	0.012
122	56	-0.104	0.016
123	90	-0.122	0.017
124	180	-0.141	0.019
125	335	-0.138	0.047
126	365	-0.144	0.036

RC=RC688 AD=AD542 PCT_REPL=60

OBS	TIME	DRY	WET
116	28	0.035	0.032
117	56	-0.110	0.038
118	90	-0.129	0.042
119	180	-0.151	0.049
120	365	-0.155	0.055

RC=RC688(3) AD=AD541 PCT_REPL=30

OBS	TIME	DRY	WET
133	28	-0.118	0.016
134	56	-0.122	0.023
135	90	-0.145	0.025
136	180	-0.167	0.026
137	335	-0.161	0.043
138	365	-0.167	0.041

RC=RC688(3) AD=AD536(2) PCT_REPL=60

OBS	TIME	DRY	WET
127	28	-0.174	0.027
128	56	-0.184	0.033
129	90	-0.199	0.033
130	180	-0.213	0.035
131	335	-0.196	0.063
132	365	-0.205	0.051

RC=RC688(3) AD=AD542 PCT_REPL=30

OBS	TIME	DRY	WET
139	28	-0.113	0.011
140	56	-0.123	0.017
141	90	-0.140	0.015
142	180	-0.165	0.017
143	332	-0.165	0.034
144	365	-0.169	0.035

RC=RC688(3) AD=AD542 PCT_REPL=60

OBS	TIME	DRY	WET
145	28	-0.219	0.027
146	56	-0.241	0.037
147	90	-0.258	0.036
148	180	-0.273	0.038
149	332	-0.256	0.060
150	365	-0.259	0.059

(Continued)

Table 3 (Concluded)

RC=RC688(3) AD=AD544(75 PCT_REPL=30

OBS	TIME	DRY	WET
151	28	-0.115	0.018
152	56	-0.133	0.025
153	90	-0.143	0.025
154	180	-0.160	0.026
155	327	-0.167	0.050
156	365	-0.167	0.050

RC=RC688(3) AD=AD544(98 PCT_REPL=30

OBS	TIME	DRY	WET
157	28	-0.124	0.017
158	56	-0.142	0.026
159	90	-0.155	0.027
160	180	-0.174	0.028
161	327	-0.179	0.047
162	365	-0.179	0.047

RC=RC688(3) AD=AD548 PCT_REPL=30

OBS	TIME	DRY	WET
163	28	-0.114	0.016
164	56	-0.138	0.020
165	90	-0.153	0.020
166	180	-0.165	0.024
167	320	-0.168	0.038
168	365	-0.173	0.038

RC=RC688(3) AD=AD570 PCT_REPL=30

OBS	TIME	DRY	WET
169	28	0.004	0.002
170	56	-0.076	0.009
171	90	-0.085	0.011
172	180	-0.078	0.016
173	365	-0.087	0.025

RC=RC688(3) AD=AD570 PCT_REPL=60

OBS	TIME	DRY	WET
174	28	0.004	0.005
175	56	-0.077	0.011
176	90	-0.079	0.017
177	180	-0.078	0.026
178	365	-0.095	0.044

Table 4

Drying Shrinkage and Lime-Water Expansion of 1- by 1- by 11-3/4-in. Prisms Made with Cement RC-705 and Different Pozzolans, Length Change, Percent

RC=RC705 AD= PCT_REPL=.

OBS	TIME	DRY	WET
179	28	0.008	0.008
180	56	-0.090	0.016
181	90	-0.101	0.019
182	180	-0.111	0.025
183	365	-0.123	0.038

RC=RC705 AD=AD505 PCT_REPL=30

OBS	TIME	DRY	WET
184	28	0.008	0.008
185	56	-0.076	0.010
186	90	-0.082	0.014
187	180	-0.101	0.021
188	365	-0.098	0.030

RC=RC705 AD=AD505 PCT_REPL=60

OBS	TIME	DRY	WET
189	28	0.011	0.010
190	56	-0.066	0.010
191	90	-0.077	0.014
192	180	-0.091	0.021
193	365	-0.083	0.035

RC=RC705 AD=AD506 PCT_REPL=30

OBS	TIME	DRY	WET
194	28	0.010	0.009
195	56	-0.088	0.012
196	90	-0.093	0.016
197	180	-0.112	0.027
198	365	-0.110	0.034

RC=RC705 AD=AD506 PCT_REPL=60

OBS	TIME	DRY	WET
199	28	0.014	0.014
200	56	-0.103	0.016
201	90	-0.111	0.020
202	180	-0.122	0.028
203	365	-0.194	0.043

RC=RC705 AD=AD507 PCT_REPL=30

OBS	TIME	DRY	WET
204	28	0.008	0.006
205	56	-0.079	0.013
206	90	-0.089	0.016
207	180	-0.103	0.024
208	365	-0.103	0.0[illegible]6

RC=RC705 AD=AD507 PCT_REPL=60

OBS	TIME	DRY	WET
209	28	0.011	0.010
210	56	-0.087	0.012
211	90	-0.099	0.015
212	180	-0.111	0.021
213	365	-0.102	0.033

(Continued)

Table 4 (Continued)

PC=PC705 AD=AD509 PCT_REPL=30

OBS	TIME	DRY	WET
214	28	0.007	0.007
215	56	-0.086	0.014
216	90	-0.098	0.016
217	180	-0.114	0.026
218	365	-0.115	0.038

PC=PC705 AD=AD509 PCT_REPL=60

OBS	TIME	DRY	WET
219	28	0.007	0.008
220	56	-0.087	0.013
221	90	-0.101	0.017
222	180	-0.111	0.023
223	365	-0.106	0.037

PC=PC705 AD=AD510 PCT_REPL=30

OBS	TIME	DRY	WET
224	28	0.014	0.015
225	56	-0.084	0.023
226	90	-0.098	0.026
227	180	-0.114	0.036
228	365	-0.117	0.050

PC=PC705 AD=AD510 PCT_REPL=60

OBS	TIME	DRY	WET
229	28	0.018	0.019
230	56	-0.075	0.023
231	90	-0.980	0.030
232	180	-0.114	0.038
233	365	-0.120	0.056

PC=PC705 AD=AD511 PCT_REPL=30

OBS	TIME	DRY	WET
234	28	0.006	0.006
235	56	-0.088	0.014
236	90	-0.098	0.016
237	180	-0.112	0.024
238	365	-0.114	0.032

PC=PC705 AD=AD511 PCT_REPL=60

OBS	TIME	DRY	WET
239	28	0.008	0.007
240	56	-0.081	0.011
241	90	-0.093	0.014
242	180	-0.100	0.018
243	365	-0.094	0.032

PC=PC705 AD=AD512 PCT_REPL=30

OBS	TIME	DRY	WET
244	28	0.012	0.013
245	56	-0.081	0.021
246	90	-0.089	0.023
247	180	-0.101	0.030
248	365	-0.105	0.039

PC=PC705 AD=AD512 PCT_REPL=60

OBS	TIME	DRY	WET
249	28	0.018	0.020
250	56	-0.050	0.019
251	90	-0.058	0.028
252	180	-0.073	0.038
253	365	-0.071	0.054

(Continued)

Table 4 (Continued)

RC=RC705 AD=AD513 PCT_REPL=30

OBS	TIME	DRY	WET
254	28	0.007	0.007
255	56	-0.096	0.014
256	90	-0.103	0.017
257	180	-0.114	0.024
258	365	-0.119	0.032

RC=RC705 AD=AD513(A) PCT_REPL=60

OBS	TIME	DRY	WET
259	28	0.010	0.006
260	56	-0.053	0.028
261	90	-0.060	0.052
262	180	-0.082	0.071
263	365	-0.078	0.091

RC=RC705 AD=AD518 PCT_REPL=30

OBS	TIME	DRY	WET
264	28	0.012	0.012
265	56	-0.104	0.019
266	90	-0.123	0.022
267	180	-0.141	0.029
268	365	-0.149	0.037

RC=RC705 AD=AD518 PCT_REPL=60

OBS	TIME	DRY	WET
269	28	0.014	0.015
270	56	-0.132	0.013
271	90	-0.161	0.014
272	180	-0.191	0.016
273	365	-0.193	0.024

RC=RC705 AD=AD536 PCT_REPL=30

OBS	TIME	DRY	WET
274	28	0.019	0.019
275	56	-0.128	0.020
276	90	-0.162	0.022
277	180	-0.190	0.031
278	365	-0.209	0.038

RC=RC705 AD=AD536 PCT_REPL=60

OBS	TIME	DRY	WET
279	28	-0.273	0.028
280	56	-0.285	0.030
281	90	-0.305	0.030
282	180	-0.335	0.033
283	335	-0.278	0.080
284	365	-0.304	0.051

(Continued)

Table 4 (Continued)

RC=RC705 AD=AD536(2) PCT_REPL=30

OBS	TIME	DRY	WET
285	28	-0.142	0.019
286	56	-0.149	0.022
287	90	-0.173	0.024
288	180	-0.194	0.026
289	335	-0.146	0.079
290	365	-0.192	0.042

RC=RC705 AD=AD541 PCT_REPL=60

OBS	TIME	DRY	WET
291	28	0.029	0.030
292	56	-0.339	0.032
293	90	-0.345	0.032
294	180	-0.346	0.043
295	365	-0.344	0.051

RC=RC705 AD=AD542 PCT_REPL=30

OBS	TIME	DRY	WET
296	28	0.029	0.030
297	56	-0.198	0.034
298	90	-0.217	0.038
299	180	-0.227	0.042
300	365	-0.246	0.051

RC=RC705 AD=AD542 PCT_REPL=60

OBS	TIME	DRY	WET
301	28	0.031	0.033
302	56	-0.115	0.037
303	90	-0.132	0.040
304	180	-0.145	0.047
305	365	-0.147	0.052

RC=RC705 AD=AD548 PCT_REPL=30

OBS	TIME	DRY	WET
306	28	-0.128	0.025
307	56	-0.154	0.032
308	90	-0.169	0.031
309	180	-0.178	0.033
310	320	-0.175	0.052
311	365	-0.175	0.052

(Continued)

Table 4 (Concluded)

PC=PC705 AD=AD570 PCT_REPL=30

OBS	TIME	DRY	WET
312	28	0.009	0.010
313	56	-0.084	0.014
314	90	-0.092	0.019
315	180	-0.088	0.025
316	365	-0.097	0.031

PC=PC705(A) AD=AD536 PCT_REPL=60

OBS	TIME	DRY	WET
317	28	0.029	0.029
318	56	-0.331	0.034
319	90	-0.344	0.035
320	180	-0.345	0.044
321	365	-0.345	0.053

PC=PC705(A) AD=AD542 PCT_REPL=30

OBS	TIME	DRY	WET
322	28	-0.136	0.017
323	56	-0.151	0.026
324	90	-0.170	0.022
325	180	-0.189	0.025
326	332	-0.180	0.042
327	365	-0.181	0.042

Table 5

Comparative Chemical Analyses of Two Portland Cements Made With and Without a Preheater

Chemical Data, %	Type II RC-763 No Preheater	Type II RC-764 Preheater
SiO_2	22.4	23.1
Al_2O_3	4.1	3.8
Fe_2O_3	2.9	3.1
CaO	62.8	62.7
MgO	4.2	4.5
SO_3	2.0	2.0
Ignition loss	1.2	1.0
Acid-soluble alkalies		
Na_2O	0.09	0.11
K_2O	0.54	0.55
Total as Na_2O	0.45	0.47
Water-soluble alkalies		
Na_2O	0.01	0.03
K_2O	0.21	0.36
Total as Na_2O	0.15	0.27
TiO_2	0.21	0.19
P_2O_5	0.06	0.08
Mn_2O_3	0.10	0.10
Insoluble residue	0.63	0.63
Calculated compounds		
C_3A	6	5
C_3S	48	44
C_2S	28	33
C_4AF	9	9

Table 6

Comparison of Chemical Data for Eight Portland Cements from Seven Dry Process Plants Using Preheaters

Chemical Data, %	Cements							
	Colorado RC-715 Type I	Georgia RC-733 Type I	Ohio RC-764 Type I	Texas RC-736 Types I, II	Colorado RC-753 Type II	Colorado RC-754 Type II	Texas RC-737 Type III	Colorado RC-832 Type V
SiO_2	20.7	21.9	23.1	21.6	21.4	21.8	20.9	22.6
Al_2O_3	5.8	4.7	3.8	4.0	4.0	3.7	2.8	3.3
Fe_2O_3	2.4	2.2	3.1	3.2	3.9	4.4	4.9	5.3
CaO	64.7	65.4	62.7	64.8	63.7	63.8	64.4	63.3
MgO	1.3	0.7	4.5	2.0	1.4	1.4	1.6	1.3
SO_3	3.1	2.7	2.0	2.2	2.5	2.3	3.4	1.8
Ignition loss	1.0	2.3	1.0	1.2	1.9	1.2	1.4	1.2
Acid-soluble alkalies								
Na_2O	0.31	0.03	0.11	0.16	0.20	0.17	0.11	0.18
K_2O	0.90	0.33	0.55	0.75	0.66	0.61	0.46	0.55
Total as Na_2O	0.90	0.25	0.47	0.65	0.63	0.57	0.41	0.54
Water-soluble alkalies								
Na_2O	0.08	0.00	0.03	0.04	0.06	0.04	0.02	
K_2O	0.62	0.03	0.36	0.49	0.44	0.61	0.29	
Total as Na_2O	0.49	0.02	0.27	0.36	0.35	0.30	0.21	
TiO_2		0.30	0.19	0.19	0.15	0.14	0.14	0.11
P_2O_5		0.08	0.08	0.04	0.09	0.08	0.06	0.12
Mn_2O_3		0.08	0.10	0.01	0.20	0.20	0.01	0.15
Insoluble residue	0.19	0.19	0.63	1.20	0.19	0.03	0.14	0.28

(Continued)

Table 6 (Concluded)

	Cements							
Chemical Data, %	Colorado RC-715 Type I	Georgia RC-733 Type I	Ohio RC-764 Type I	Texas RC-736 Types I, II	Colorado RC-753 Type II	Colorado RC-754 Type II	Texas RC-737 Type III	Colorado RC-832 Type V
Calculated Compounds								
C_3A	11	9	5	5	4	2	0	0
C_3S	55	57	44	62	57	56	67	51
C_2S	18	20	33	15	18	20	10	26
C_4AF	7	7	9	10	12	14	0	0
$2C_3A + C_4AF$	30	24	19	20	20	18	--	--
$(C_4AF + C_2F)SS$	--	--	--	--	--	--	14	16

Table 7

Comparative Chemical Data for Eight Cements (Six with Slag) from Six Sources

	Cements							
Chemical Data, %	Alabama RC-751 Type I	Alabama RC-752 Type I-S	Michigan RC-758 Type I-S	Pennsylvania RC-769 Type I-S	Pennsylvania RC-770 Type I	Pennsylvania RC-833 Type I-S	Germany USAEC-IC-1 Type I-S	Germany USAEC-IC-2 Type I-S
SiO_2	20.8	23.00	22.3	23.9	20.4	24.5	27.5	24.8
Al_2O_3	5.6	5.9	6.1	7.9	5.8	7.2	10.6	8.4
Fe_2O_3	2.5	2.1	2.0	2.2	2.3	2.0	1.7	1.9
CaO	64.0	61.3	60.8	55.8	62.4	53.2	50.6	54.8
MgO	2.8	2.0	3.7	4.9	3.9	6.3	4.5	4.1
SO_3	2.5	3.0	2.6	2.4	2.4	2.5	2.8	1.9
Ignition loss	1.6	2.0	1.1	2.0	2.2	3.0	0.1	2.2
Acid-soluble alkalies								
Na_2O	0.14	0.17	0.27	0.19	0.17	0.19	0.24	0.27
K_2O	0.40	0.40	1.08	0.27	0.24	0.23	0.58	0.82
Total as Na_2O	0.40	0.43	0.98	0.37	0.33	0.34	0.60	0.81
Water-soluble alkalies								
Na_2O	0.02	0.02	0.03	0.02	0.03		0.009	0.008
K_2O	0.13	0.03	0.66	0.03	0.11		0.018	0.226
Total as	0.11	0.04	0.47	0.04	0.10		0.021	0.157
TiO_2	0.24	0.24	0.26	0.34	0.30	0.27		
P_2O_5	0.04	0.16	0.08	0.17	0.05	0.20		
Mn_2O_2	0.03	0.03	0.07	0.36	0.23	0.31		
Insoluble residue	0.22				0.29	0.41	0.10	1.52

(Continued)

Table 7 (Concluded)

	Cements							
Chemical Data, %	Alabama RC-751 Type I	Alabama RC-752 Type I-S	Michigan RC-758 Type I-S	Pennsylvania RC-769 Type I-S	Pennsylvania RC-770 Type I	Pennsylvania RC-833 Type I-S	Germany USAEC-IC-1 Type I-S	Germany USAEC-IC-2 Type I-S
Calculated compounds								
C_3A	11.0				11.0			
C_3S	55.0				52.0			
C_2S	18.0				19.0			
C_4AF	8.0				7.0			
$2C_3A + C_4AF$	30.0				29.0			

Table 8

Comparative Chemical Data, Type I-P for Blended Cements With Pozzolans and Type I Cement From the Same Source

Chemical Data, %	Arizona* RC-732 Type I-P	Arizona* RC-731 Type I	Illinois* RC-726(2) Type I-P	Illinois* RC-725 Type I	Michigan* RC-719 Type I-P	Michigan* RC-720 Type I
SiO_2	25.6	21.7	24.8	20.6	25.3	21.1
Al_2O_3	6.8	3.7	8.2	4.6	9.8	5.7
Fe_2O_3	2.8	2.5	4.7	2.9	4.0	2.8
CaO	55.1	64.4	53.7		54.2	62.6
MgO	3.8	4.4	2.8	3.6	2.9	3.7
SO_3	2.0	2.1	3.0	2.6	2.6	2.6
Ignition Loss	1.8	2.6	1.0	1.3	1.3	1.1
Acid-Soluble Alkalies						
Na_2O	0.12	0.14	0.13	0.12	0.27	0.32
K_2O	0.44	0.56	0.70	1.00	0.60	0.72
Total as Na_2O	0.41	0.51	0.59	0.78	0.66	0.79
Water-Soluble Alkalies						
Na_2O	0.01	0.01	0.03	0.06	0.05	0.05
K_2O	0.10	0.12	0.39	0.80	0.25	0.31
Total as Na_2O	0.08	0.07	0.29	0.59	0.21	0.25
TiO_2	0.45	0.27	0.30	0.23		
P_2O_5	0.02	0.18	0.07	0.04		
Mn_2O_3	0.03	0.03	0.03	0.03		
Insoluble Residue		0.56		0.13	12.75	0.18
Calculated Compounds						
C_3A		6		7		10
C_3S		63		61		45
C_2S		15		13		26
C_4AF		8		9		8
$2C_3A + C_4AF$		19		23		29

(Continued)

* Different type of cement from one plant.

(Sheet 1 of 3)

Table 8 (Continued)

Chemical Data, %	Missouri* RC-738 Type I	Missouri* RC-739 Type I-P	Missouri* RC-740 Type I-P**	South Carolina* RC-729 Type I	South Carolina* RC-730 Type I-P
SiO_2	20.1	25.4	23.7	20.7	25.8
Al_2O_3	5.6	8.1	7.6	5.5	10.8
Fe_2O_3	2.3	5.0	3.8	2.3	3.1
CaO	62.5	52.3	56.3	64.9	53.6
MgO	3.4	2.7	3.2	1.1	0.9
SO_3	2.7	1.8	2.3	2.7	3.1
Ignition loss	2.3	2.6	1.5	2.1	1.7
Acid-soluble alkalies					
Na_2O	0.10	0.11	0.08	0.08	0.07
K_2O	0.70	0.58	0.60	0.40	0.29
Total as	0.56	0.49	0.57	0.34	0.26
Water-soluble alkalies					
Na_2O	0.02	0.02	0.02	0.08	0.01
K_2O	0.34	0.28	0.32	0.40	0.06
Total as Na_2O	0.24	0.21	0.22	0.09	0.05
TiO_2		0.39	0.33	0.27	0.46
P_2O_5		0.16	0.16	0.17	0.16
Mn_2O_3		0.05	0.05	0.01	0.01
Insoluble residue	0.17			0.18	
Calculated compounds					
C_3A	11			11	
C_3S	53			59	
C_2S	17			14	
C_4AF	7			7	
$2C_3A + C_4AF$	29			28	

(Continued)

* Different types of cement from one plant.
** Made with bottom ash.

(Sheet 2 of 3)

Table 8 (Concluded)

Chemical Data, %	Tennessee* RC-742 Type I-P	Tennessee* RC-741 Type I	Texas* RC-807 Type I-P**	Texas* RC-807(A) Type I
SiO_2	25.3	22.0	25.3	20.6
Al_2O_3	9.7	5.4	8.1	5.1
Fe_2O_3	3.0	2.4	4.6	4.1
CaO	54.3	64.9	58.1	65.7
MgO	1.8	1.5	1.6	0.9
SO_3	2.8	2.2	2.7	2.5
Ignition Loss	1.7	1.3	0.5	1.0
Acid-Soluble Alkalies				
Na_2O	0.12	0.13	0.23	0.11
K_2O	0.34	0.29	0.38	0.25
Total as Na_2O	0.34	0.32	0.48	0.27
Water-Soluble Alkalies				
Na_2O	0.02	0.02		
K_2O	0.13	0.13		
Total as Na_2O	0.10	0.10		
TiO_2	0.37	0.22	0.41	
P_2O_5	0.12	0.14	0.16	
Mn_2O_3	0.04	0.04	0.34	
Insoluble Residue		0.34	8.40	0.17
Calculated Compounds				
C_3A		10		7
C_3S		51		64
C_2S		25		11
C_4AF		7		12
$2C_3A + C_4AF$		28		26

* Different types of cement from one plant.
** Made with fly ash AD-577.

(Sheet 3 of 3)

Table 9

Data for 12 Blended Cements, 7- and

28-Day Heat of Hydration

State	RC	Class	Heat of Hydration, cal/g 7 days	28 days
Alabama	752	1-S*	80	86
Michigan	758	1-S	71	83
Pennsylvania	769	1-S	80	90
Arizona	732	1-P**	71	81
Illinois	726(2)	1-P	82	91
Michigan	735	1-P	75	83
Missouri (same	739	1-P	70	77
plant)	740	1-P (with bottom ash)	74	81
Texas	742	1-P	76	87
	745	1-P	65	78
	807	1-P	76	87
South Carolina	730	1-P	69	80

* 1-S - blast-furnace slag replaces portland cement 25 percent to 65 percent by weight (ASTM C 595-75, Sec. 2.2).

** 1-P - pozzolan replaces 15 percent to 40 percent portland cement by weight (ASTM C 595-75, Sec. 2.8).

Table 10

7- and 28-Day Heat of Hydration Values for Laboratory Cements and Cement-Mineral Admixture Combinations

				Portland Cement					
				RC-688			RC-705		
				% Replacement by Volume			% Replacement by Volume		
	Class	Source* of Pozzolan	Age days	0% cal/g	30% cal/g	60% cal/g	0% cal/g	30% cal/g	60% cal/g
Cement only			7	85	--	--	68	--	--
			28	96	--	--	79	--	--
Combined with									
AD-505	F	SB	7		70	49		56	47
			28		83	62		65	56
AD-506	F	L	7		73	53		56	45
			28		85	67		70	57
AD-507	F	SB	7		70	48		57	41
			28		83	64		66	48
AD 509	F	L	7		72	51		52	49
			28		82	66		62	56
AD-510	C	L	7		82	73		67	69
			28		90	81		76	77
AD-511	F	SB	7		68	47		55	39
			28		83	62		68	45
AD-512	F	SB	7		74	52		63	43
			28		86	73		72	63
AD-513	C	L	7		80	51		63	27
			28		93	79		78	50
AD-515	N	VC	7		75	59		60	46
			28		86	68		72	61
AD-536		SF	7		73	56		61	52
			28		90	78		74	58

* SB - subbituminous coal; L - lignite coal; VC - volcanic ash; SF - silica fume (silica condensed fume).

Table 11

Relation of CaO by Chemical Analysis and Surface Area to Selected Heat of Hydration Data

Structures Laboratory Serial No.	Source of Fly Ash*	CaO %	Surface Area, cm^2/cc	7-day Heat of Hydration for Cement Blended with 30 Percent Pozzolan by Solid Volume: RC-688 Type I cal/g	RC-705 Type II cal/g
AD-510	L	29.9	8,750	82	67
AD-513	L	21.0	12,790	80	63
AD-512	SB	20.3	12,830	74	63
AD-506	L	19.8	6,780	73	56
AD-509	L	13.4	4,690	72	54
AD-505	SB	11.1	9,130	70	56
AD-507	SB	4.2	7,660	70	54
AD-511	B	2.7	6,870	68	55

* L = lignite; SB = subbituminous; B = bituminous.

Table 12

Chemical Data and Comparison of Alkali Availability for 15 Materials

Structures Laboratory Serial No.	Class	Chemical data, %: SiO_2 %	Al_2O_3 %	Fe_2O_3	CaO %	MgO %	SO_3 %	Moisture Loss %	Ignition Loss %	Alkali Availability: Total (fusion) Na_2O	K_2O	Total as Na_2O	Acid Soluble Na_2O	K_2O	Total as Na_2O	Available (28 days) Na_2O	K_2O	Total as Na_2O	Water Soluble Na_2O	K_2O	Total as Na_2O
AD-518	N	68.0	17.4	5.30	2.3	0.8	0.9	1.4	1.6	2.11	1.59	3.16	0.16	0.19	0.28	0.18	0.26	0.35	0.02	0.00	0.02
AD-516	N	60.5	13.3	4.0	6.7	1.12	0.3	0.2	3.8	4.27	2.77	6.09	0.40	0.15	0.50	0.92	0.74	1.41	--	--	--
AD-515	N	53.0	16.7	7.1	8.0	3.4	0.2	--	1.3	1.82	3.48	4.11	0.39	0.14	0.48	0.70	0.76	1.20	--	--	--
AD-513	C	38.1	24.7	4.6	21.0	4.4	1.6	0.1	0.1	1.30	0.58	1.65	0.67	0.28	0.85	0.47	0.28	0.65	0.01	0.00	0.01
AD-510	C	23.5	16.4	9.1	29.9	8.4	5.3	0.3	1.1	3.28	0.39	3.54	2.51	0.25	2.67	2.40	0.23	2.55	0.63	0.05	0.66
AD-509	F	49.7	17.8	6.3	13.1	4.9	1.1	0.1	0.2	4.00	1.76	5.16	1.31	0.57	1.69	1.38	0.38	1.63	0.38	0.01	0.39
AD-506	F	50.4	18.4	4.2	19.8	3.5	1.3	0.2	0.8	0.57	0.53	0.92	0.20	0.12	0.28	0.21	0.18	0.33	0.00	0.00	0.00
AD-512	F	43.3	19.7	7.7	20.3	3.3	1.8	0.2	1.1	0.45	1.54	1.46	0.13	0.29	0.32	0.23	0.77	0.74	0.00	0.00	0.00
AD-505	F	45.9	21.4	10.9	11.1	2.5	1.1	0.1	3.8	0.37	1.93	1.64	0.04	0.20	0.17	0.12	0.60	0.51	0.01	0.01	0.02
AD-507	F	44.9	21.8	17.2	4.8	0.7	1.1	0.3	5.7	1.38	2.18	2.81	0.34	0.30	0.54	0.50	0.78	1.01	0.14	0.03	0.16
AD-511	F	45.4	24.3	15.0	2.7	1.1	0.7	0.3	4.3	0.38	2.61	2.10	0.06	0.36	0.30	0.14	0.88	0.72	0.02	0.03	0.04
AD-560	F	53.2	31.1	5.2	2.8	1.4	0.2	0.5	1.3	0.43	3.50	2.73	--	--	--	0.12	0.94	0.74	0.001	0.0001	0.00
AD-570	F	47.8	30.6	7.6	2.1	1.1	0.6	0.2	3.7	0.37	2.78	2.20	--	--	--	0.12	0.94	0.74	--	--	--
AD-517	F	49.6	26.3	12.4	1.4	0.7	0.5	0.1	3.0	0.26	2.38	1.83	0.05	0.30	0.25	0.07	0.61	0.47	--	--	--
AD-537	Slag	38.6	9.0	0.4	33.5	14.8	0.0	--	2.3	--	--	--	0.27	0.40	0.53	0.06	0.14	0.15	0.01	0.01	0.02
AD-536	Silica fume	96.0	1.3	0.1	0.3	0.0	0.1	1.3	1.1	0.15	0.24	0.31	0.03	0.00	0.03	0.06	0.03	0.08	--	--	--

Table 13

Silica Fumes, Chemical Analysis Expressed as Oxides, percent

Result	Silica Fumes, Structures Laboratory No. AD- 536	536(2)	536(3)	536(4)	541	542	543	544(75)	544(98)	545	546	548	549	550	551	552	553	557	558
SiO_2	96.0	93.9	96.6	95.8	95.2	89.4	92.6	90.1	83.6	42.6	73.7	91.5	67.4	67.4	93.6	93.3	80.7	71.2	85.1
Al_2O_3	1.3	0.7	1.0	1.1	0.3	0.8	0.6	1.7	0.5	4.7	4.0	1.0	4.8	4.7	0.6	0.6	3.6	2.4	1.7
Fe_2O_3	0.1	0.1	0.1	0.1	0.4	1.5	0.3	1.9	0.4	6.2	13.9	1.5	11.3	1.2	0.3	1.0	0.6	14.6	1.8
CaO	0.3	0.8	--	0.2	0.3	0.6	0.3	1.6	0.2	3.7	2.3	0.9	4.0	0.7	0.4	0.5	0.3	1.1	0.7
MgO	0.0	0.3	0.2	0.1	0.3	1.5	0.2	0.4	0.4	2.8	3.8	0.7	1.9	12.0	1.0	1.1	9.5	0.5	1.5
SO_3	0.1	0.2	0.3	0.1	0.1	0.1	0.1	0.1	0.4	2.1	0.2	0.2	0.3	0.4	0.5	0.0	0.3	0.2	0.3
Na_2O	0.15	0.15	0.22	--	0.12	0.26	0.13	0.29	0.16	1.14	0.44	0.18	0.20	2.60	0.10	0.17	0.48	0.19	1.24
K_2O	0.24	0.24	0.43	--	0.35	0.72	0.32	0.55	0.34	7.44	1.17	0.58	0.62	3.09	0.71	1.70	1.58	0.63	2.27
Total as Na_2O	0.31	0.31	0.50	--	0.35	0.73	0.34	0.65	0.38	6.04	1.21	0.56	0.61	4.63	0.57	1.29	1.52	0.60	2.73
Mn_2O_3	--	0.00	--	--	0.01	0.16	0.01	0.11	0.00	22.62	0.85	0.23	1.78	0.26	0.02	0.08	0.14	0.93	0.31
Cr_2O_3	--	0.00	--	--	0.00	0.00	0.00	0.00	0.04	0.02	0.04	0.01	0.05	1.47	0.00	0.10	0.66	0.01	0.00
Cl^-	--	0.01	--	--	0.05	0.17	0.04	0.11	0.21	0.01	0.06	0.09	0.01	4.14	0.05	0.00	0.08	0.17	1.06
Moisture loss	0.3	0.4	0.2	0.3	0.2	0.4	0.2	0.6	0.7	0.7	0.0	0.4	2.1	1.1	0.3	0.5	0.8	0.2	0.6
Loss on ignition	1.1	1.0	0.7	1.3	1.3	3.5	2.7	3.8	11.9	7.2	1.0	2.0	14.1	4.8	3.4	1.4	1.7	11.2	4.3
Total	99.59	97.50	99.73	98.9	98.63	99.11	97.50	101.26	98.85	103.23	101.46	99.29	108.56	103.86	100.98	100.45	100.44	103.33	100.88

NOTE: Alkalies were determined from solutions of $LiBO_2$ fusions.

Table 14

Silica Fumes, Chemical Analysis Expressed as Elements, Percent

	Silica Fumes																		
	Structures Laboratory No. AD-																		
Result	536	536(2)	536(3)	536(4)	541	542	543	544(75)	544(98)	545	546	548	549	550	551	552	553	557	558
Si	44.9	43.9	45.2	44.8	44.5	41.8	43.3	42.1	39.1	19.9	34.4	42.8	31.5	31.5	43.8	43.6	37.7	33.3	39.8
Al	0.7	0.4	0.5	0.6	0.2	0.4	0.3	0.9	0.3	2.5	2.1	0.5	2.5	2.5	0.3	0.8	1.9	1.3	0.9
Fe	0.1	0.0	0.1	0.1	0.3	1.0	0.2	1.3	0.3	4.3	9.7	1.0	7.9	0.8	0.2	0.7	0.4	10.2	1.3
Ca	0.2	0.6	--	0.1	0.2	0.4	0.2	1.1	0.1	2.6	1.6	0.6	2.9	0.5	0.3	0.4	0.2	0.8	0.5
Mg	0.00	0.7	0.1	0.2	0.2	0.9	0.1	0.2	0.2	1.7	2.4	0.4	1.2	7.2	0.6	0.7	6.0	0.3	0.9
S	0.0	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.1	0.8	0.1	0.1	0.1	0.1	0.2	0.0	0.1	0.1	0.1
Na	0.11	0.11	0.16	--	0.09	0.19	0.10	0.22	0.12	0.85	0.33	0.13	0.15	1.93	0.07	0.13	0.36	0.14	0.92
K	0.20	0.20	0.36	--	0.29	0.60	0.27	0.46	0.28	6.18	0.97	0.48	0.51	2.57	0.59	1.41	1.31	0.52	1.88
Mn	--	0.00	--	--	0.01	0.11	0.01	0.08	0.00	15.83	0.59	0.16	1.25	0.18	0.01	0.06	0.10	0.65	0.22
Cr	--	0.00	--	--	0.00	0.00	0.00	0.00	0.03	0.01	0.03	0.01	0.03	1.00	0.00	0.07	0.45	0.01	0.00
Cl^-	--	0.01	--	--	0.05	0.17	0.04	0.11	0.21	0.01	0.06	0.09	0.01	4.14	0.05	0.00	0.08	0.17	1.06
Moisture loss	0.3	0.4	0.2	0.3	0.2	0.4	0.3	0.6	0.7	0.7	0.0	0.4	2.1	1.1	0.3	0.5	0.8	0.2	0.6
Loss on ignition	1.1	1.0	0.7	1.3	1.3	3.5	2.7	3.8	11.9	7.2	1.0	2.0	14.1	4.8	3.4	1.4	1.7	11.2	4.3
O	--	52.6	--	--	52.7	50.4	52.5	49.0	46.6	37.3	46.7	51.2	35.8	41.6	50.2	50.2	48.8	41.1	47.6
Total		100.0			100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

NOTE: Alkalies were determined from solutions of $LiBO_2$ fusions.

APPENDIX A: CREEP OF CEMENT PASTE

Specimens

1. Three 3- by 6-in. cylindrical specimens were fabricated from each of seventeen cement paste mixtures. An embedment strain gage was placed in each specimen prior to casting to measure axial strains. Monofilament nylon line was used to position and secure the strain gage. A total of 51 specimens were cast, 2 creep specimens and a control specimen for each mixture.

2. Twenty-four hours prior to loading, all specimens were demolded and the ends of the creep specimens were surface ground to ensure parallelism of the ends. All specimens were sealed in an asphaltic membrane to minimize moisture loss during the testing period.

Loading Procedure

3. The creep loading frames (Figure A1) consisted of header plates bearing on the ends of the loaded specimens, springs to sustain the loads, and threaded reaction rods similar to that described in CRD-C 54-77. Creep specimens were placed in the loading frame taking care in aligning the specimens to avoid eccentric loading. The number of specimens per loading rig varied from two to four depending on the number of specimens to be loaded on a given date to the same sustained load. Axial loads were applied incrementally to 20 percent of ultimate cylinder strength using a hydraulic hand pump. Control specimens were stored in an unloaded condition near companion creep specimens. All specimens were maintained at approximately 75° F and 50 percent relative humidity during the testing period.

Strain Measurements

4. Strain gages embedded in the creep and control specimens were read immediately prior to loading, upon attaining full load, and periodically throughout the test period (Tables A1-A17). In addition, elastic strain readings were obtained on the creep specimens at each load increment. Elastic strains were determined by taking the difference in strain measurements immediately before and after loading. Elastic strains and moduli of elasticity computed on this basis are summarized in Table A18.

Strains in Control Specimens

5. Control specimens were subjected to the same environmental conditions as the creep specimens throughout the loading period. Results of these strain measurements are presented in Tables A1-A17. Also, control strain-time relationships for each mixture are shown in Plates A1-A17. With the exception of a few measurements at very early ages, all control strains were compressive indicating shrinkage of the cement paste. Maximum strains in the control specimens ranged from approximately 400 to 1200 millionths, with an overall average shrinkage of approximately 800 millionths.

Strains in Creep Specimens

6. The strain data obtained from the loaded creep specimens during the course of the testing period represented total strains, i.e., those which included the elastic deformation upon application of load, and the time-dependent deformations due to load and chemical or physical volume changes with the specimen. Results of individual measurements of total strains for each creep specimen are given in Tables A1-A17. In addition, average total strain-time relationships for each mixture are presented in Plates A18-A34.

7. Specific creep strains for a given time were determined by subtracting the elastic strain from the total strain, correcting this value for the appropriate volume-change (control) strain, and dividing it by the applied load. Results obtained in this manner are shown for each mixture in Tables A1-A17. In addition, specific creep strain-time relationships are presented in Plates A35-A50.

8. To form a numerical basis of comparison for the various mixtures, curves of best fit based on a least-squares analysis were computed for the creep strain-time relationships. These equations were then used to compute specific creep strains at 1 year after loading as shown in Table A19.

Paste Mixtures

9. Mixture combinations and test ages of specimens from the 17 pastes are tabulated below:

Mixture and Loading Data for 17 Pastes

Used for Creep Testing

Mixture No.	Cement RC-	Cement Replaced by	W/C or W/S	Loading Age days
1	688(3)	60% AD-510	0.60	28
2	688(3)	60% AD-510	0.40	2
3	688(3)	60% AD-507	0.40	7
4	688(3)	--	0.40	2
5	688(3)	60% AD-510	0.40	7
6	688(3)	30% AD-510	0.40	7
7	688(3)	30% AD-507	0.40	7
8	688(3)	60% AD-510	0.40	28
9	688(3)	--	0.60	28
10	735(IP)	--	0.40	7
11	772(II)	--	0.40	7
12	742(IP)	--	0.40	7
13	752(IS)	--	0.40	7
14	688(3)	--	0.40	7
15	688(3)	60% AD-510	0.25	2
16	688(3)	--	0.25	2
17	688(3)	--	0.40	28

10. As mentioned earlier, comparison may be made of the effect of creep on various parameters. Some of these comparisons are made in the following section.

Discussion

11. Results of the creep tests are summarized in Table A20. In general, specific creep strains were inversely proportional to the modulus of elasticity of the creep specimens (Figure A2).

12. For a given cement, water-cement ratio, and cement replacement material, specific creep decreased with an increased age at loading (Figure A3). This was also true of comparable mixtures without cement replacement material.

Under these conditions, the specific creep of cement paste containing 60 percent replacement material by volume was significantly higher at the earlier loading ages than that of paste without any cement replacement. With a water-cement ratio of 0.40 and 7 days' age at loading, specific creep increased with an increase in cement replacement volume (Figure A4). In each case, the specific creep of specimens containing AD-507 cement replacement were approximately 30 percent higher than those containing AD-510. Given a water-cement ratio of 0.25 and 2 days' age at loading, the addition of cement replacement (AD-510) in the amount of 60 percent by volume resulted in a 30 percent increase in specific creep.

13. Specific creep of the paste specimens containing "special cements" (Mixtures 10-13) ranged from 0.9311 to 1.2108 millionths per psi with an overall average of 1.1094 millionths per psi. These specimens had a water-cement ratio of 0.40 and were loaded at 7 days' age. In comparison, specimens containing "conventional cement" (Mixtures 6 and 7) and 30 percent cement replacement with the same water-cement ratio and age at loading had an average specific creep of 1.1566 millionths per psi.

14. The specific creep of paste specimens loaded at 2 days' age increased by more than 100 percent with an increase in water-cement ratio from 0.25 to 0.40. In contrast, creep specimens loaded at 28 days' age exhibited a decrease in specific creep of more than 150 percent when the water-cement ratio was increased from 0.40 to 0.60. This is contrary to expectations and causes one to question the test results associated with Mixture 9. In this case, the strain measurements, both elastic and time-dependent, are significantly lower than any other mixture tested.

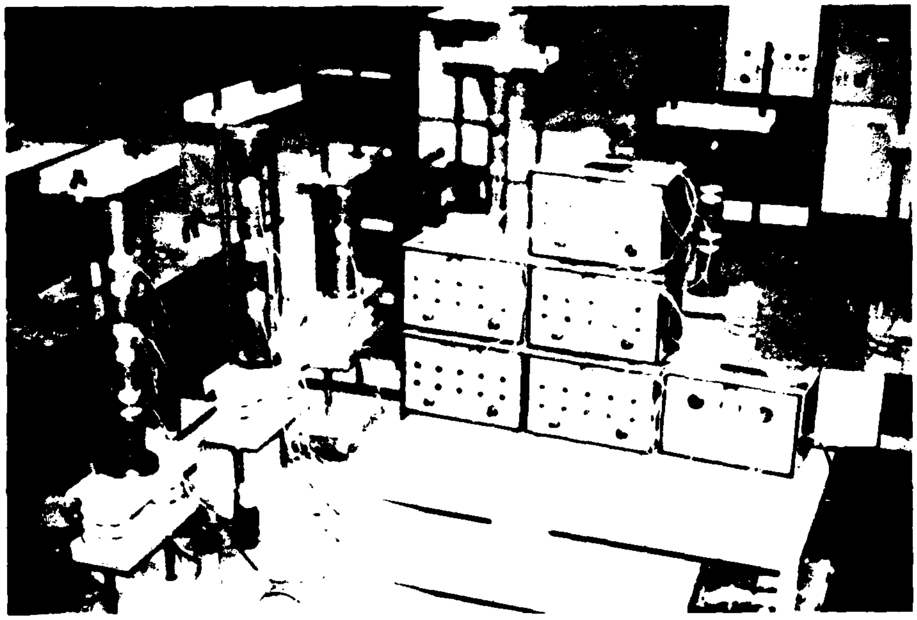


Figure A1. Creep test apparatus

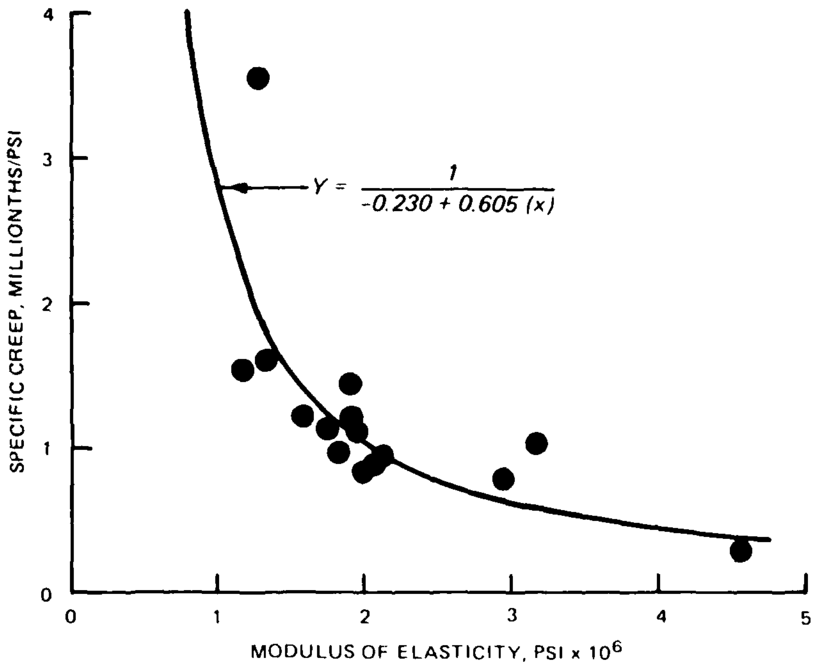


Figure A2. Relation of creep and modulus of elasticity

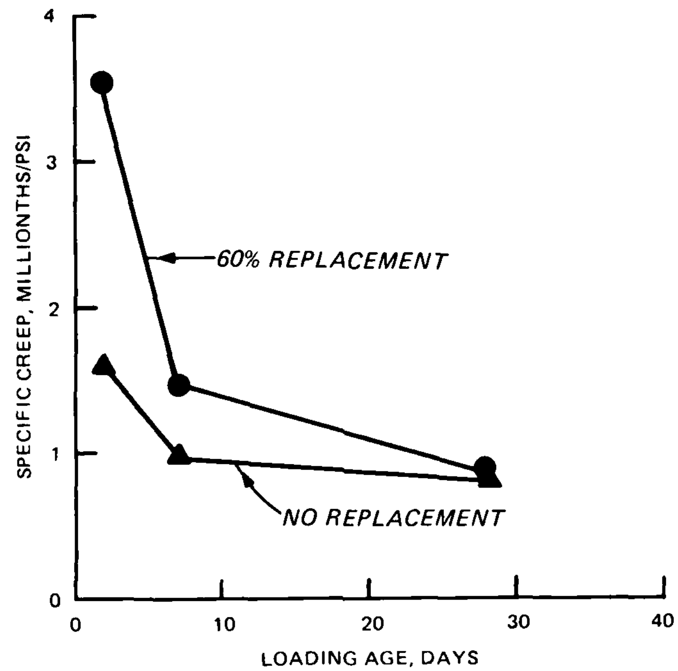


Figure A3. The effect of loading age and cement replacement material on creep

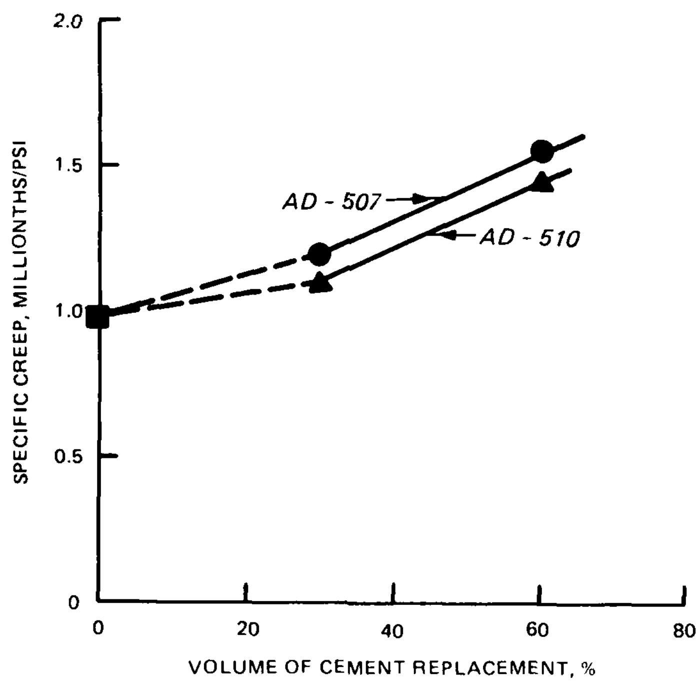


Figure A4. The effect of different types of cement replacement material on creep

Table A1

Strain Measurements,

Mixture No. 1

Time, days	Total Strain, Millionths Gage No. 13	Gage No. 14	Avg	Creep Strain, Millionths	Control Strain, Millionths	Corrected Creep Strain, Millionths	Specific Creep, Millionths/psi
0	119	156	137	0	0	0	0
0.12	119	158	138	1	-8	9	0.048
0.92	137	190	163	26	16	10	0.054
5	145	191	168	31	18	13	0.070
6	160	206	183	46	41	5	0.027
7	170	217	193	56	59	-3	-0.016
8	206	235	220	83	77	8	0.043
11	210	242	226	89	105	-16	-0.086
12	250	280	265	128	147	-19	-0.102
13	299	328	313	176	207	-31	-0.167
14	280	310	295	158	187	-29	-0.156
15	285	315	300	163	195	-32	-0.172
18	305	325	315	178	217	-39	-0.210
19	284	306	295	158	197	-39	-0.210
20	300	315	307	170	217	-47	-0.253
22	325	338	331	194	237	-43	-0.231
27	376	385	380	243	297	-54	-0.290
32	460	470	465	328	337	-9	-0.048
46	565	590	577	440	457	-17	-0.091
64	635	650	642	505	477	28	0.151
76	720	725	722	585	532	53	0.285
95	830	825	827	690	602	88	0.473
105	920	910	915	779	687	91	0.489
113	920	940	930	793	735	58	0.312
147	1030	1030	1030	893	750	143	0.769
165	1075	1060	1068	931	775	156	0.839

Table A2

Strain Measurements,

Mixture No. 2

Time, days	Total Strain, Millionths Gage No. 37	Gage No. 38	Avg	Creep Strain, Millionths	Control Strain, Millionths	Corrected Creep Strain, Millionths	Specific Creep, Millionths/psi
0	175	162	169	0	0	0	0
0.2	272	257	265	96	-29	125	0.601
3	460	445	453	284	-58	342	1.644
4	543	525	534	366	-4	370	1.776
5	615	592	604	435	46	389	1.870
6	685	660	673	504	101	403	1.938
7	725	700	713	544	131	413	1.986
11	840	800	820	652	206	446	2.142
12	885	850	868	699	251	448	2.154
13	930	895	913	744	286	458	2.202
14	965	932	949	780	318	462	2.221
17	995	950	973	804	336	468	2.250
19	980	935	958	789	309	480	2.308
20	995	950	973	804	322	482	2.317
21	1019	972	996	827	338	489	2.351
25	1026	976	1001	833	338	495	2.377
26	1033	985	1009	841	346	495	2.377
27	1040	992	1016	848	348	500	2.401
32	1060	1010	1035	867	361	506	2.430
39	1125	1065	1095	927	411	516	2.478
45	1120	1055	1088	919	406	513	2.466
52	1185	1122	1154	985	456	529	2.543
55	1177	1115	1146	978	451	527	2.531
60	1178	1110	1144	976	446	530	2.546
67	1205	1135	1170	1002	466	536	2.575
74	1264	1200	1232	1064	528	536	2.575
82	1250	1176	1213	1045	506	539	2.589
89	1202	1130	1166	998	466	532	2.555
102	1266	1185	1226	1057	516	541	2.601
125	1300	1216	1285	1090	541	549	2.637
144	1390	1310	1350	1182	631	551	2.647
166	1372	1290	1331	1163	616	547	2.627
181	1340	1258	1299	1131	581	550	2.642

Table A3

Strain Measurements,

Mixture No. 3

Time, days	Total Strain, Millionths Gage No. 13	Gage No. 14	Avg	Creep Strain, Millionths	Control Strain, Millionths	Corrected Creep Strain, Millionths	Specific Creep, Millionths/psi
0	375	330	352	0	0	0	0
0.04	425	357	319	39	0	39	0.093
0.79	515	440	478	126	2	124	0.296
2	557	475	516	164	-5	169	0.403
3	590	511	550	198	-8	206	0.492
4	582	512	547	195	-39	234	0.558
7	658	595	627	274	-16	290	0.692
9	690	636	663	311	-12	323	0.771
10	700	640	670	318	-14	332	0.792
11	708	646	677	325	-19	344	0.821
14	770	715	743	390	22	368	0.878
15	782	725	754	401	28	373	0.890
16	795	736	766	413	30	383	0.914
17	792	736	764	412	18	395	0.943
18	790	730	760	408	11	397	0.947
21	800	745	773	420	10	410	0.979
22	818	761	790	437	19	418	0.998
23	832	775	804	451	28	423	1.001
24	856	800	828	476	48	428	1.021
25	861	806	834	481	54	427	1.019
29	870	817	844	491	55	436	1.041
30	900	845	873	500	76	444	1.060
31	915	865	890	538	94	444	1.060
32	935	885	910	558	108	450	1.074
35	950	898	924	572	120	452	1.079
37	940	892	916	564	106	458	1.093
38	950	900	925	573	121	452	1.079
39	965	915	940	588	126	462	1.101
43	990	935	963	610	144	466	1.112
44	986	935	961	608	146	462	1.103
45	995	944	970	617	148	469	1.119
50	1042	961	1002	649	166	483	1.153
57	1056	1001	1029	676	206	470	1.122
63	1076	1025	1051	698	227	471	1.124
70	1128	1080	1104	752	276	476	1.135
73	1135	1085	1110	758	288	470	1.121
78	1145	1102	1124	771	296	475	1.134
85	1172	1130	1151	799	322	477	1.137
92	1225	1182	1204	851	374	477	1.138
100	1235	1187	1211	859	381	478	1.140
107	1215	1170	1193	840	378	462	1.103
120	1270	1221	1246	893	418	475	1.134
143	1330	1280	1305	953	476	477	1.137
162	1400	1358	1379	1027	551	476	1.135
184	1432	1385	1409	1056	583	473	1.129

Table A4

Strain Measurements,

Mixture No. 4

Time, days	Total Strain, Millionths Gage No. 7	Total Strain, Millionths Gage No. 8	Total Strain, Millionths Avg	Creep Strain, Millionths	Control Strain, Millionths	Corrected Creep Strain, Millionths	Specific Creep, Millionths/psi
0	471	458	465	0	0	0	0
0.04	529	513	521	57	0	57	0.092
0.81	736	715	726	261	46	215	0.347
2	920	879	900	435	128	307	0.495
5	1237	1172	1205	740	290	450	0.726
6	1264	1197	1231	766	284	482	0.777
7	1265	1198	1232	767	253	514	0.829
8	1292	1225	1259	794	250	544	0.877
9	1310	1232	1271	807	238	569	0.918
12	1365	1296	1331	866	244	622	1.003
14	1395	1322	1359	894	254	640	1.032
15	1400	1330	1365	901	245	656	1.059
16	1405	1331	1368	904	237	667	1.076
19	1456	1386	1421	956	270	687	1.108
20	1472	1402	1437	973	280	693	1.118
21	1490	1418	1454	990	293	697	1.124
22	1495	1427	1461	997	293	704	1.135
23	1496	1423	1460	995	289	706	1.139
26	1523	1447	1485	1021	310	711	1.147
27	1542	1465	1504	1039	325	714	1.152
28	1565	1490	1528	1063	343	720	1.161
29	1580	1505	1543	1078	355	723	1.166
30	1590	1510	1550	1086	356	730	1.177
34	1602	1524	1563	1099	370	729	1.176
35	1630	1550	1590	1126	398	728	1.174
36	1650	1570	1610	1146	408	738	1.190
37	1662	1582	1622	1158	418	740	1.194
40	1667	1587	1627	1163	424	739	1.192
41	1585	1500	1543	1078	336	742	1.197
42	1590	1507	1549	1084	343	741	1.195
43	1585	1520	1553	1088	353	735	1.185
48	1706	1620	1663	1199	456	743	1.198
49	1710	1625	1668	1203	460	743	1.198
50	1717	1632	1675	1210	468	742	1.197
55	1738	1650	1694	1230	490	740	1.193
62	1785	1694	1740	1275	533	742	1.197
68	1795	1700	1748	1283	553	730	1.177
75	1840	1747	1794	1329	593	736	1.187
78	1745	1651	1698	1234	508	726	1.170
83	1765	1665	1715	1251	528	723	1.165
90	1790	1695	1743	1278	557	721	1.163
97	1827	1732	1780	1315	593	722	1.165
105	1850	1756	1803	1339	624	715	1.152
112	1820	1710	1765	1301	598	703	1.133
125	1912	1795	1854	1389	678	711	1.147
148	2000	1882	1941	1477	783	694	1.119
167	2104	1985	2045	1580	868	712	1.148
189	2155	2032	2093	1629	933	696	1.123
204	2155	2159	2157	1693	954	739	1.191

Table A5

Strain Measurements,

Mixture No. 5

Time, days	Total Strain, Millionths Gage No. 10	Gage No. 11	Avg	Creep Strain, Millionths	Control Strain, Millionths	Corrected Creep Strain, Millionths	Specific Creep, Millionths/psi
0	332	354	343	0	0	0	0
0.04	372	386	379	36	9	27	0.044
0.81	562	575	569	226	40	186	0.300
2	660	692	676	333	78	255	0.411
5	GF	885	885	542	158	384	0.619
6		900	900	557	148	409	0.660
7		873	873	530	114	416	0.671
8		905	905	562	122	440	0.710
9		900	900	557	99	458	0.739
12		968	968	625	116	509	0.821
14		1020	1020	677	174	503	0.811
15		1011	1011	668	134	534	0.861
16		1016	1016	673	139	534	0.861
19		1076	1076	733	169	564	0.910
20		1090	1090	747	175	572	0.923
21		1095	1095	747	179	573	0.924
22		1096	1096	753	170	583	0.940
23		1090	1090	747	161	586	0.945
26		1109	1109	766	169	597	0.963
27		1125	1125	782	182	600	0.968
28		1141	1141	798	194	604	0.974
29		1240	1240	897	252	645	1.040
30		1175	1175	832	214	618	0.997
34		1167	1167	824	209	615	0.992
35		1202	1202	859	234	625	1.008
36		1222	1222	879	246	633	1.021
37		1238	1238	895	264	631	1.018
40		1240	1240	897	259	638	1.029
41		1227	1227	884	244	640	1.032
42		1240	1240	897	252	645	1.040
43		1255	1255	912	262	650	1.048
48		1260	1260	917	264	653	1.053
49		1255	1255	912	259	653	1.053
50		1266	1266	923	269	654	1.055
55		1273	1273	930	272	658	1.061
62		1312	1312	969	299	670	1.081
68		1320	1320	977	304	673	1.085
75		1365	1365	1022	337	685	1.105
78		1362	1362	1019	340	679	1.095
83		1375	1375	1032	342	690	1.113
90		1394	1394	1051	359	692	1.116
97		1445	1445	1102	404	698	1.126
105		1449	1449	1106	401	705	1.137
112		1400	1400	1057	354	703	1.134
125		1464	1464	1121	404	714	1.156

(Continued)

Table A5 (Concluded)

Time, days	Total Strain, Millionths Gage No. 10	Gage No. 11	Avg	Creep Strain, Millionths	Control Strain, Millionths	Corrected Creep Strain, Millionths	Specific Creep, Millionths/psi
146		1515	1515	1172	439	733	1.182
167		1590	1590	1247	509	738	1.190
189		1606	1606	1263	514	749	1.208
204		1580	1580	1237	484	753	1.215
232		1600	1600	1257	497	760	1.226
257		1570	1570	1227	466	471	1.227
266		1515	1515	1172	421	751	1.211

Table A6

Strain Measurements,

Mixture No. 6

Time, days	Total Strain, Millionths Gage No. 1	Gage No. 2	Avg	Creep Strain, Millionths	Control Strain, Millionths	Corrected Creep Strain, Millionths	Specific Creep, Millionths/psi
0	480	414	447	0	0	0	0
0.85	680	592	636	189	-29	218	0.253
2	740	647	694	247	-49	296	0.343
6	990	880	935	488	45	443	0.514
7	1050	938	994	547	80	467	0.542
8	1090	980	1035	588	105	483	0.560
9	1131	1018	1075	628	125	503	0.583
12	1235	1127	1181	734	187	547	0.635
14	1260	1145	1203	756	190	566	0.657
15	1270	1162	1216	769	190	579	0.672
16	1275	1165	1220	773	185	588	0.682
19	1322	1218	1270	823	193	630	0.731
22	1374	1270	1322	875	247	628	0.729
23	1357	1248	1303	856	217	639	0.741
26	1368	1262	1315	868	215	653	0.758
27	1410	1306	1358	911	255	656	0.761
28	1426	1316	1371	924	265	659	0.765
29	1410	1308	1359	912	250	662	0.768
30	1392	1292	1342	895	223	672	0.780
33	1436	1336	1386	939	251	688	0.798
34	1470	1378	1424	977	289	688	0.798
35	1466	1368	1417	970	272	698	0.810
41	1450	1360	1405	958	260	698	0.810
42	1435	1345	1390	943	245	698	0.810
47	1480	1390	1435	988	268	720	0.835
54	1522	1440	1481	1034	297	737	0.855
61	1530	1455	1493	1046	310	736	0.853
76	1512	1451	1481	1034	321	714	0.828
89	1550	1505	1527	1080	321	759	0.881
107	1626	1586	1606	1159	380	779	0.904
121	1576	1540	1558	1111	325	786	0.912
134	1600	1570	1585	1138	347	791	0.918
139	1624	1610	1617	1170	380	790	0.916
148	1716	1705	1710	1236	460	776	0.900
166	1735	1740	1737	1290	475	815	0.945
180	1800	1795	1797	1350	535	815	0.945
198	1765	1765	1765	1318	495	823	0.955
210	1820	1820	1820	1373	565	808	0.937
229	1860	1860	1860	1413	585	828	0.960
239	1900	1870	1885	1438	595	843	0.978
247	1910	1900	1905	1458	600	850	0.986
254	1920	1925	1922	1475	645	830	0.963
281	1980	1980	1980	1533	710	823	0.955
299	2020	2030	2025	1578	715	863	1.000

Table A7

Strain Measurements,

Mixture No. 7

Time, days	Total Strain, Millionths Gage No. 4	Gage No. 5	Avg	Creep Strain, Millionths	Control Strain, Millionths	Corrected Creep Strain, Millionths	Specific Creep, Millionths/psi
0	547	540	544	0	0	0	0
1	705	690	698	154	-25	179	0.208
2	760	740	750	207	-50	257	0.298
6	975	945	960	417	-13	430	0.498
7	1025	995	1010	467	5	462	0.535
8	1056	1027	1042	498	15	483	0.560
9	1092	1054	1073	530	25	505	0.585
12	1180	1135	1158	614	61	553	0.642
14	1205	1157	1181	638	57	581	0.673
15	1222	1170	1196	653	50	603	0.699
16	1220	1170	1195	652	45	606	0.704
19	1260	1205	1233	689	50	639	0.741
22	1320	1267	1294	750	92	658	0.763
23	1301	1250	1276	732	65	667	0.774
26	1316	1260	1288	745	67	678	0.786
27	1355	1295	1325	782	92	690	0.800
28	1366	1307	1337	793	95	698	0.810
29	1360	1296	1328	785	85	700	0.811
30	1335	1276	1306	762	60	702	0.814
33	1335	1272	1304	760	57	703	0.816
34	1390	1325	1358	814	88	726	0.842
35	1367	1300	1333	790	65	725	0.841
41	1367	1300	1334	790	45	745	0.864
42	1360	1292	1362	783	35	748	0.867
47	1390	1310	1350	807	44	763	0.885
54	1390	1330	1360	817	35	782	0.907
61	1425	1340	1382	839	50	789	0.915
76	1395	1302	1348	805	0	805	0.934
89	1450	1355	1402	859	40	819	0.950
107	1513	1417	1465	921	75	846	0.982
121	1461	1357	1409	865	22	843	0.978
134	1488	1373	1400	856	31	827	0.959
139	1513	1405	1459	915	51	864	1.002
148	1613	1505	1559	1015	150	865	1.003
166	1635	1515	1575	1031	150	881	1.022
180	1680	1570	1625	1081	205	876	1.016
198	1695	1575	1635	1091	210	881	1.022
210	1730	1600	1665	1121	235	886	1.028
229	1770	1650	1710	1166	285	881	1.022
239	1790	1660	1725	1181	295	886	1.028
247	1815	1690	1752	1208	330	878	1.019
254	1830	1705	1767	1223	320	903	1.018
281	1895	1775	1835	1291	385	906	1.051
299	1920	1800	1860	1316	410	906	1.051

Table A8

Strain Measurements,

Mixture No. 8

Time, days	Total Strain, Millionths Gage No. 31	Gage No. 32	Avg	Creep Strain, Millionths	Control Strain, Millionths	Corrected Creep Strain, Millionths	Specific Creep, Millionths/psi
0	546	585	566	0	0	0	0
0.08	560	645	603	37	20	17	0.015
0.90	648	807	728	162	33	129	0.114
2	695	895	795	230	38	192	0.170
5	1308	1497	1403	837	563	274	0.243
6	1345	1506	1426	860	583	277	0.245
7	1392	1510	1451	886	610	276	0.244
8	1442	1524	1483	918	633	285	0.252
9	1465	1510	1488	922	638	284	0.252
13	1523	GF	1523	957	628	329	0.291
14	1565		1565	999	660	339	0.300
15	1602		1602	1036	681	355	0.314
16	1630		1630	1064	700	364	0.322
19	1640		1640	1074	690	384	0.340
21	1622		1622	1056	656	400	0.354
22	1635		1635	1069	661	408	0.361
23	1656		1656	1090	647	443	0.392
27	1658		1658	1092	659	433	0.384
28	1665		1665	1099	659	440	0.390
29	1675		1675	1109	660	449	0.398
34	1696		1696	1130	663	467	0.414
41	1764		1764	1180	700	480	0.425
47	1770		1770	1204	688	516	0.457
54	1845		1845	1279	740	539	0.477
57	1847		1847	1281	728	553	0.490
62	1850		1850	1284	720	564	0.500
69	1890		1890	1324	738	586	0.519
76	1965		1965	1399	798	601	0.532
84	1965		1965	1399	770	629	0.557
91	1928		1928	1362	728	634	0.562
104	2025		2025	1459	768	691	0.612
127	2090		2090	1524	788	736	0.652
146	2202		2202	1636	823	763	0.676
168	2215		2215	1649	848	801	0.709
183	2195		2195	1629	808	821	0.727
211	2232		2232	1666	813	853	0.756
236	2235		2235	1669	763	906	0.802
245	2195		2195	1629	706	923	0.818
255	2156		2156	1590	673	917	0.812
263	2165		2165	1599	658	941	0.833
280	2132		2132	1566	618	948	0.840
292	2155		2155	1589	640	949	0.841
299	2118		2118	1552	604	948	0.840
314	2105		2105	1539	580	959	0.849
328	2108		2108	1542	588	954	0.845
346	2152		2152	1586	604	982	0.870
360	2058		2058	1492	513	979	0.867
366	2095		2095	1529	554	1005	0.890

Table A9

Strain Measurements,

Mixture No. 9

Time, days	Total Strain, Millionths Gage No. 10	Total Strain, Millionths Gage No. 11	Total Strain, Millionths Avg	Creep Strain, Millionths	Control Strain, Millionths	Corrected Creep Strain, Millionths	Specific Creep, Millionths/psi
0	237	259	248	0	0	0	0
0.04	250	272	261	13	-4	17	0.015
0.15	GF	285	285	37	-4	41	0.036
0.90		302	302	54	-18	72	0.064
2		318	318	70	-10	80	0.071
5		350	350	102	-15	117	0.104
6		392	392	144	15	129	0.114
7		405	405	157	12	145	0.128
8		395	395	147	2	145	0.128
9		380	380	132	-13	145	0.128
12		412	412	164	5	159	0.141
13		430	430	182	20	162	0.143
14		418	418	170	2	168	0.149
20		450	450	202	18	184	0.163
21		435	435	187	0	187	0.166
26		480	480	232	30	202	0.179
33		520	520	272	55	217	0.192
40		556	556	308	76	232	0.205
55		575	575	327	75	252	0.223
68		665	665	417	142	275	0.244
86		760	760	512	216	296	0.262
100		732	732	484	181	303	0.268
113		767	767	519	210	309	0.274
118		798	798	550	226	324	0.287
127		920	920	672	360	312	0.276
145		1010	1010	762	415	347	0.307
159		1055	1055	807	484	323	0.286
177		1030	1030	782	490	292	0.259
189		1130	1130	882	550	332	0.294
208		1200	1200	952	600	352	0.312
218		1260	1260	1012	670	342	0.303
226		1270	1270	1022	685	337	0.298
233		1265	1265	1017	675	342	0.303
260		1360	1360	1112	750	362	0.321
278		1390	1390	1142	775	367	0.325

Table A10

Strain Measurements,

Mixture No. 10

Time, days	Total Strain, Millionths: Gage No. 34	Total Strain, Millionths: Gage No. 35	Total Strain, Millionths: Avg	Creep Strain, Millionths	Control Strain, Millionths	Corrected Creep Strain, Millionths	Specific Creep, Millionths/psi
0	722	732	727	0	0	0	0
0.08	800	812	806	79	20	59	0.052
0.88	1006	1020	1013	286	43	243	0.215
2	1120	1136	1128	401	57	344	0.305
5	1818	1850	1834	1107	589	518	0.459
6	1885	1915	1900	1173	627	546	0.484
7	1941	1980	1961	1234	653	581	0.515
8	2015	2052	2034	1307	685	622	0.551
9	2050	2090	2070	1343	695	648	0.574
13	2152	2195	2174	1447	715	732	0.648
14	2205	2248	2227	1500	747	753	0.667
15	2247	2292	2270	1543	775	768	0.680
16	2292	2335	2314	1587	805	782	0.692
19	2327	2370	2349	1622	807	815	0.721
21	2322	2367	2345	1618	777	841	0.744
22	2340	2385	2363	1636	787	849	0.752
23	2365	2412	2389	1662	800	862	0.763
27	2392	2439	2416	1689	795	894	0.791
28	2400	2450	2425	1698	800	898	0.795
29	2410	2460	2435	1708	800	908	0.805
31	2450	2502	2476	1749	815	934	0.827
41	2525	2576	2551	1024	850	974	0.862
47	2535	2586	2561	1834	843	991	0.877
54	2615	2670	2643	1916	900	1016	0.899
57	2617	2671	2644	1917	895	1022	0.905
62	2625	2685	2655	1928	895	1033	0.915
69	2670	2725	2698	1971	910	1061	0.939
76	2740	2800	2770	2043	970	1073	0.950
84	2745	2800	2773	2046	961	1085	0.961
91	2740	2800	2770	2043	955	1088	0.964
104	2810	2865	2838	2111	995	1116	0.988
127	2880	2940	2910	2183	1052	1131	1.002
146	2990	3060	3025	2298	1155	1143	1.012
168	3012	3080	3046	2319	1165	1154	1.022
183	3000	3075	3038	2311	1149	1162	1.029
211	3042	3120	3081	2354	1183	1171	1.037
236	3022	3100	3061	2334	1155	1179	1.044
245	2970	3057	3014	2287	1115	1172	1.038
255	2940	3040	2990	2263	1095	1168	1.035
263	2941	3030	2986	2259	1087	1172	1.038
280	2900	2996	2948	2221	1050	1171	1.037
292	2930	3020	2975	2248	1080	1168	1.035
299	2890	2985	2938	2211	1045	1166	1.032
314	2875	2975	2925	2198	1034	1164	1.031
328	2895	3000	2947	2220	1051	1169	1.036
346	2930	3036	2983	2256	1058	1198	1.061
360	2828	2927	2877	2150	1020	1130	1.001
366	2874	2977	2925	2198	1074	1124	0.996

Table A11

Strain Measurements,

Mixture No. 11

Time, days	Total Strain, Millionths Gage No. 16	Total Strain, Millionths Gage No. 17	Avg	Creep Strain, Millionths	Control Strain, Millionths	Corrected Creep Strain, Millionths	Specific Creep, Millionths/psi
0	610	616	613	0	0	0	0
0.02	624	631	628	15	1	14	0.011
0.79	761	764	763	150	-11	161	0.126
4	968	981	975	362	24	338	0.265
6	1096	1091	1094	481	90	391	0.300
7	1114	1118	1116	503	66	437	0.342
8	1146	1146	1146	533	67	466	0.365
11	1261	1276	1269	656	139	516	0.404
12	1299	1310	1305	692	156	536	0.420
13	1326	1338	1332	719	169	550	0.431
14	1351	1364	1358	745	176	569	0.446
15	1366	1382	1374	761	175	586	0.459
18	1424	1446	1435	822	199	623	0.488
19	1456	1476	1466	853	220	633	0.496
20	1492	1508	1500	887	237	650	0.509
21	1526	1546	1536	923	264	659	0.516
22	1543	1566	1555	942	276	666	0.522
26	1593	1618	1606	993	290	703	0.551
27	1636	1662	1649	1036	324	712	0.558
28	1668	1696	1682	1069	346	723	0.567
29	1696	1724	1710	1097	369	728	0.570
32	1732	1762	1747	1134	386	748	0.586
34	1744	1771	1758	1145	379	766	0.600
35	1766	1791	1779	1166	394	772	0.605
36	1786	1814	1800	1187	409	778	0.610
40	1821	1848	1835	1222	430	792	0.620
41	1826	1856	1841	1228	429	799	0.626
42	1841	1876	1859	1246	439	807	0.632
47	1886	1921	1904	1291	464	827	0.648
54	1971	2006	1989	1376	519	857	0.671
60	2028	2061	2045	1432	549	883	0.692
67	2118	2146	2132	1519	609	910	0.713
70	2126	2168	2147	1534	620	914	0.716
75	2160	2202	2181	1568	644	924	0.724
82	2218	2262	2240	1627	684	943	0.739
89	2311	2346	2329	1716	754	962	0.754
97	2341	2388	2365	1752	784	968	0.758
104	2336	2386	2361	1748	774	974	0.763
117	2461	2510	2485	1873	864	1009	0.790
140	2596	2643	2620	2007	964	1043	0.817
159	2716	2753	2735	2122	1059	1063	0.833
181	2793	2826	2810	2197	1114	1083	0.848
196	2806	2832	2819	2206	1104	1102	0.864
224	2882	2906	2894	2281	1174	1107	0.868

(Continued)

Table A11 (Concluded)

Time, days	Total Strain, Millionths Gage No. 16	Gage No. 17	Avg	Creep Strain, Millionths	Control Strain, Millionths	Corrected Creep Strain, Millionths	Specific Creep, Millionths/psi
249	2886	2902	2894	2281	1172	1109	0.869
258	2876	2892	2884	2271	1159	1112	0.871
268	2813	2835	2824	2211	1114	1097	0.860
277	2860	2883	2872	2259	1164	1095	0.858
293	2946	2846	2896	2283	1159	1124	0.881
305	*GF*	2896	2896	2283	1197	1086	0.851
312		2876	2876	2263	1169	1094	0.857
327		2863	2863	2250	1164	1086	0.851
340		2821	2821	2208	1168	1040	0.815
358		2936	2936	2328	1224	1099	0.861
365		2896	2896	2283	1189	1094	0.857

Table A12

Strain Measurements,

Mixture No. 12

Time, days	Total Strain, Millionths Gage No. 19	Gage No. 20	Avg	Creep Strain, Millionths	Control Strain, Millionths	Corrected Creep Strain, Millionths	Specific Creep, Millionths/psi
0	754	721	738	0	0	0	0
0.04	786	750	768	31	0	31	0.024
0.79	1011	1000	1005	268	0	268	0.210
4	1335	1317	1326	589	72	516	0.404
6	1470	1440	1455	718	115	603	0.473
7	1510	1480	1495	758	63	695	0.545
8	1533	1500	1517	779	65	714	0.560
11	1676	1645	1661	923	140	783	0.614
12	1717	1682	1700	962	155	807	0.632
13	1750	1719	1735	997	171	826	0.647
14	1774	1740	1757	1020	145	374	0.685
15	1787	1755	1771	1034	150	884	0.693
18	1851	1820	1836	1098	170	928	0.727
19	1882	1850	1866	1129	185	944	0.740
20	1911	1880	1896	1158	205	953	0.747
21	1950	1920	1935	1198	230	968	0.759
22	1966	1935	1951	1213	240	973	0.763
26	2025	1980	2003	1265	250	1015	0.795
27	2063	2032	2048	1310	276	1034	0.810
28	2090	2058	2074	1337	300	1037	0.812
29	2115	2085	2100	1363	332	1031	0.808
32	2145	2113	2129	1392	344	1048	0.821
34	2148	2116	2132	1395	327	1068	0.837
35	2164	2137	2151	1413	336	1077	0.844
36	2180	2150	2165	1428	350	1078	0.844
40	2210	2182	2196	1459	360	1099	0.861
41	2215	2185	2200	1463	355	1108	0.868
42	2222	2195	2209	1471	360	1111	0.871
47	2255	2227	2241	1504	375	1129	0.884
54	2315	2292	2304	1566	415	1151	0.902
60	2342	2320	2331	1594	436	1158	0.907
67	2408	2385	2397	1659	486	1173	0.919
70	2420	2400	2410	1673	496	1177	0.927
75	2440	2420	2430	1693	507	1186	0.929
82	2480	2460	2470	1733	536	1197	0.938
89	2540	2528	2534	1797	600	1197	0.938
97	2560	2548	2554	1817	605	1212	0.949
104	2560	2545	2553	1815	590	1225	0.960
117	2615	2610	2613	1875	642	1233	0.966
140	2700	2692	2696	1959	710	1249	0.978
159	2792	2785	2789	2051	800	1251	0.980
181	2835	2833	2834	2097	841	1256	0.984
196	2825	2830	2828	2090	828	1262	0.989
224	2870	2870	2870	2133	860	1273	0.997
249	2830	2836	2833	2096	825	1271	0.996

(Continued)

Table A12 (Concluded)

Time, days	Total Strain, Millionths Gage No. 19	Gage No. 20	Avg	Creep Strain, Millionths	Control Strain, Millionths	Corrected Creep Strain, Millionths	Specific Creep, Millionths/psi
258	2815	2820	2818	2080	805	1275	0.999
268	2750	2755	2753	2015	740	1275	0.999
277	2800	2805	2803	2065	762	1303	1.021
293	2785	2785	2785	2048	750	1298	1.017
305	2794	2804	2799	2062	765	1297	1.016
312	2770	2780	2775	2038	742	1296	1.015
327	2755	2765	2760	2022	728	1294	1.014
340	2758	2762	2760	2022	730	1293	1.013
358	2805	2810	2807	2070	771	1299	1.018
365	2756	2763	2759	2022	733	1289	1.010

Table A13

Strain Measurements,

Mixture No. 13

Time, days	Total Strain, Millionths Gage No. 22	Gage No. 23	Avg	Creep Strain, Millionths	Control Strain, Millionths	Corrected Creep Strain, Millionths	Specific Creep, Millionths/psi
0	780	705	742	0	0	0	0
0.04	856	777	817	74	-6	80	0.057
0.81	1108	1010	1059	317	-20	337	0.238
4	1518	1376	1447	705	61	644	0.456
5	1612	1460	1536	794	82	712	0.505
6	1692	1540	1616	874	111	763	0.541
7	1736	1570	1653	911	95	816	0.578
8	1787	1620	1704	961	110	851	0.603
11	1925	1742	1834	1091	160	931	0.660
12	1976	1790	1883	1141	185	956	0.678
13	2042	1840	1941	1199	215	984	0.697
14	2096	1892	1994	1252	250	1002	0.710
15	2135	1927	2031	1289	270	1019	0.722
19	2230	2035	2133	1390	322	1068	0.757
20	2280	2070	2175	1433	345	1088	0.771
21	2322	2115	2219	1476	375	1101	0.780
23	2372	2162	2267	1525	410	1115	0.790
25	2432	2220	2326	1584	440	1144	0.810
27	2450	2228	2339	1597	433	1164	0.825
28	2470	2248	2359	1617	447	1170	0.829
29	2495	2270	2383	1640	461	1179	0.836
33	2542	2315	2429	1686	485	1201	0.851
34	2547	2320	2434	1691	485	1206	0.855
35	2563	2332	2448	1705	495	1210	0.858
40	2615	2380	2498	1755	520	1235	0.875
47	2710	2465	2588	1845	580	1265	0.897
53	2710	2465	2588	1845	615	1230	0.872
60	2855	2604	2730	1987	680	1307	0.926
63	2870	2615	2743	2000	695	1305	0.925
68	2900	2645	2773	2030	720	1310	0.928
75	2961	2700	2831	2088	758	1330	0.943
82	3056	2792	2924	2182	835	1347	0.954
90	3096	2820	2958	2216	860	1356	0.961
97	3100	2825	2963	2220	850	1370	0.971
110	3210	2924	3067	2325	935	1390	0.985
133	3340	3060	3200	2458	1030	1428	0.012
152	3475	3320	3398	2655	1160	1495	1.060
174	3550	3390	3470	2728	1195	1533	1.086
189	3552	3395	3474	2731	1193	1538	1.090
211	3622	3464	3543	2801	1240	1561	1.106
242	3620	3475	3548	2805	1227	1578	1.118
251	3585	3438	3511	2769	1197	1572	1.114
261	3522	3375	3449	2706	1142	1564	1.108
270	3552	3412	3482	2740	1163	1577	1.117

(Continued)

Table A13 (Concluded)

Time, days	Total Strain, Millionths Gage No. 22	Gage No. 23	Avg	Creep Strain, Millionths	Control Strain, Millionths	Corrected Creep Strain, Millionths	Specific Creep, Millionths/psi
286	3550	3400	3475	2733	1163	1570	1.112
298	3570	3410	3490	2748	1185	1563	1.107
305	3535	3356	3446	2703	1157	1546	1.096
320	3522	3315	3418	2676	1155	1521	1.078
334	3525	3323	3424	2681	1155	1526	1.082
352	3577	3360	3468	2725	1203	1523	1.079
366	3530	3314	3422	2671	1166	1505	1.067

Table A14

Strain Measurements,

Mixture No. 14

Time, days	Total Strain, Millionths Gage No. 25	Total Strain, Millionths Gage No. 26	Total Strain, Millionths Avg	Creep Strain, Millionths	Control Strain, Millionths	Corrected Creep Strain, Millionths	Specific Creep, Millionths/psi
0	734	825	780	0	0	0	0
0.04	773	925	849	70	-3	73	0.052
0.80	940	1132	1036	257	-15	272	0.193
4	1200	1410	1305	526	27	499	0.354
5	1251	1462	1357	572	29	548	0.388
6	1305	1520	1413	633	39	594	0.421
7	1306	1525	1416	636	9	627	0.444
8	1335	1550	1443	663	4	659	0.467
11	1415	1631	1523	744	4	740	0.524
12	1442	1665	1554	774	19	755	0.536
13	1482	1710	1596	817	39	278	0.551
14	1525	1755	1640	861	64	297	0.565
15	1550	1782	1666	887	24	813	0.576
19	1625	1852	1739	959	97	862	0.611
20	1660	1890	1775	996	119	877	0.622
21	1695	1927	1811	1032	139	893	0.633
23	1736	1970	1853	1074	146	928	0.657
25	1785	2025	1905	1126	194	932	0.660
27	1785	2027	1906	1127	179	948	0.672
28	1808	2047	1928	1148	189	959	0.680
29	1825	2068	1947	1167	202	965	0.684
33	1860	2105	1983	1203	217	986	0.699
34	1865	2110	1988	1208	219	989	0.701
35	1876	2120	1998	1219	221	998	0.707
40	1920	2160	2040	1261	239	1022	0.724
47	2000	2240	2120	1341	289	1052	0.745
53	2050	2285	2168	1388	319	1069	0.758
60	2137	2370	2254	1474	379	1095	0.776
63	2155	2392	2274	1494	391	1103	0.782
68	2185	2422	2304	1524	411	1113	0.789
[illegible]5	2240	2478	2359	1580	451	1129	0.800
82	2330	2575	2453	1673	529	1144	0.811
90	2358	2610	2484	1705	549	1156	0.819
97	2370	2630	2500	1721	549	1172	0.830
110	2478	2735	2607	1827	634	1193	0.846
133	2600	2865	2733	1953	739	1214	0.860
152	2740	3012	2876	2097	869	1228	0.870
174	2798	3072	2935	2156	914	1242	0.880
189	2800	3075	2938	2158	909	1249	0.885
217	2860	3140	3000	2221	964	1257	0.891
242	2847	3130	2989	2209	960	1249	0.885
251	2816	3100	2958	2179	939	1240	0.878
261	2768	3050	2909	2130	899	1231	0.872
270	2780	3065	2923	2143	919	1224	0.867

(Continued)

Table A14 (Concluded)

Time, days	Total Strain, Millionths Gage No. 25	Gage No. 26	Avg	Creep Strain, Millionths	Control Strain, Millionths	Corrected Creep Strain, Millionths	Specific Creep, Millionths/psi
286	2762	3053	2908	2128	914	1214	0.860
298	2777	3070	2924	2144	945	1199	0.850
305	2740	3038	2889	2109	929	1181	0.837
320	2722	3019	2870	2091	929	1162	0.823
334	2730	3017	2873	2094	939	1155	0.819
352	2778	3076	2927	2147	989	1159	0.821
366	2726	3029	2878	2098	959	1139	0.807

Table A15

Strain Measurements,

Mixture No. 15

Time, days	Total Strain, Millionths: Gage No. 28	Total Strain, Millionths: Gage No. 29	Total Strain, Millionths: Avg	Creep Strain, Millionths	Control Strain, Millionths	Corrected Creep Strain, Millionths	Specific Creep, Millionths/psi
0	425	468	447	0	0	0	0
0.03	508	512	509	62	-5	67	0.047
0.80	856	820	838	392	30	362	0.257
4	1240	GF	1240	793	127	666	0.472
5	1300		1300	853	136	717	0.508
6	1345		1345	898	152	746	0.529
7	1342		1342	895	115	780	0.553
8	1360		1360	913	115	798	0.566
11	1410		1410	963	110	853	0.605
12	1430		1430	983	116	867	0.614
13	1462		1462	1015	135	880	0.624
14	1490		1490	1043	145	898	0.636
15	1509		1509	1062	150	912	0.646
19	1526		1526	1079	135	944	0.669
20	1555		1555	1108	155	953	0.675
21	1583		1583	1136	175	961	0.681
23	1617		1617	1170	200	970	0.687
25	1635		1635	1188	198	990	0.702
27	1625		1625	1178	170	1008	0.714
28	1635		1635	1188	181	1007	0.714
29	1647		1647	1200	190	1010	0.716
33	1659		1659	1212	181	1031	0.731
34	1656		1656	1209	175	1034	0.733
35	1664		1664	1217	176	1041	0.738
40	1676		1676	1229	175	1054	0.747
47	1720		1720	1273	200	1073	0.760
53	1738		1738	1291	200	1091	0.773
60	1797		1797	1350	240	1110	0.787
63	1807		1807	1360	245	1115	0.790
68	1816		1816	1369	240	1129	0.800
75	1845		1845	1398	260	1138	0.807
82	1920		1920	1473	315	1158	0.821
90	1922		1922	1475	304	1171	0.830
97	1920		1920	1473	295	1178	0.835
110	1970		1970	1523	320	1203	0.853
133	2045		2045	1598	350	1248	0.884
152	2145		2145	1698	435	1263	0.895
174	2162		2162	1715	430	1285	0.911
189	2132		2132	1685	392	1293	0.916
217	2141		2141	1694	385	1309	0.928
242	2095		2095	1648	326	1322	0.937
251	2042		2042	1595	280	1315	0.932
261	2083		2083	1636	205	1431	1.014

(Continued)

Table A15 (Concluded)

Time, days	Total Strain, Millionths Gage No. 28	Gage No. 29	Avg	Creep Strain, Millionths	Control Strain, Millionths	Corrected Creep Strain, Millionths	Specific Creep, Millionths/psi
270	1982		1982	1535	210	1325	0.939
286	1942		1942	1495	175	1320	0.936
298	1927		1927	1480	170	1310	0.928
305	1890		1890	1443	135	1308	0.927
320	1855		1855	1408	96	1312	0.930
334	1844		1844	1397	95	1302	0.923
352	1867		1867	1420	120	1300	0.921
366	1800		1800	1353	61	1292	0.916

Table A16

Strain Measurements,

Mixture No. 16

Time, days	Total Strain, Millionths Gage No. 40	Gage No. 41	Avg	Creep Strain, Millionths	Control Strain, Millionths	Corrected Creep Strain, Millionths	Specific Creep, Millionths/psi
0	540	607	574	0	0	0	0
0.17	677	743	710	137	-21	157	0.093
0.92	886	970	928	355	26	329	0.193
2	1050	1136	1093	520	89	431	0.254
3	1175	1260	1218	644	139	505	0.297
4	1242	1334	1288	715	161	554	0.326
8	1435	1532	1484	910	229	681	0.401
9	1490	1590	1540	967	260	707	0.416
10	1542	1639	1591	1017	288	729	0.429
11	1586	1682	1634	1061	314	747	0.440
14	1643	1750	1697	1123	334	789	0.465
16	1650	1778	1714	1141	334	807	0.475
17	1675	1802	1739	1165	346	819	0.482
18	1700	1830	1765	1192	360	832	0.490
22	1735	1875	1805	1232	374	858	0.505
23	1747	1892	1820	1246	379	867	0.511
24	1760	1905	1833	1259	386	873	0.514
29	1805	1957	1881	1308	404	904	0.532
36	1890	2050	1970	1397	454	943	0.555
42	1905	2076	1991	1417	458	959	0.565
49	2013	2160	2087	1513	509	1004	0.591
52	2020	2170	2095	1522	514	1008	0.593
57	2035	2197	2116	1543	521	1022	0.602
64	2076	2240	2158	1585	544	1041	0.613
71	2160	2307	2234	1660	600	1060	0.624
79	2162	2328	2245	1672	601	1071	0.630
86	2176	2343	2260	1686	604	1082	0.637
99	2245	2415	2330	1757	644	1113	0.655
122	2320	2500	2410	1837	699	1138	0.670
141	2435	2600	2518	1944	779	1165	0.686
163	2460	2640	2550	1977	799	1178	0.693
178	2450	2645	2548	1974	786	1188	0.700
206	2495	2685	2590	2017	811	1206	0.710
231	2465	2670	2568	1994	783	1211	0.713
240	2420	2642	2531	1958	749	1209	0.712
250	2392	2605	2499	1925	714	1211	0.713
259	2385	2610	2498	1924	709	1215	0.716
275	2340	2560	2450	1877	661	1216	0.716
287	2360	2570	2465	1892	666	1226	0.722
294	2320	2540	2430	1857	629	1228	0.723
309	2298	2519	2408	1835	609	1226	0.722
322	2316	2532	2424	1850	612	1238	0.729
340	2315	2519	2417	1843	595	1248	0.735
354	2243	2474	2358	1784	542	1242	0.732
365	2357	2485	2421	1847	558	1289	0.759

Table A17

Strain Measurements,

Mixture No. 17

Time, days	Total Strain, Millionths Gage No. 43	Gage No. 44	Avg	Creep Strain, Millionths	Control Strain, Millionths	Corrected Creep Strain, Millionths	Specific Creep, Millionths/psi
0	1080	985	1032	0	0	0	0
0.08	1168	1083	1126	93	-3	96	0.046
0.83	1325	1245	1285	253	-7	260	0.124
2	1435	1345	1390	358	0	358	0.170
3	1520	1433	1477	444	18	426	0.203
4	1570	1482	1526	494	18	476	0.226
8	1720	1635	1678	645	18	627	0.299
9	1775	1690	1733	700	40	660	0.314
10	1824	1736	1780	748	61	687	0.327
11	1865	1780	1823	790	78	712	0.339
14	1935	1850	1893	860	83	777	0.370
16	1965	1890	1928	895	80	815	0.388
17	1990	1916	1953	921	85	836	0.398
18	2025	1952	1989	956	98	858	0.409
22	2085	2020	2053	1020	108	912	0.434
23	2105	2043	2074	1042	118	924	0.440
24	2120	2060	2090	1058	123	935	0.445
29	2195	2142	2169	1136	143	993	0.473
36	2318	2275	2297	1264	200	1064	0.507
42	2375	2335	2355	1323	216	1107	0.527
49	2495	2462	2479	1446	283	1163	0.554
52	2520	2490	2505	1473	293	1180	0.562
57	2566	2544	2555	1523	310	1213	0.577
64	2650	2630	2640	1608	350	1258	0.599
71	2750	2730	2740	1708	413	1295	0.616
79	2800	2795	2798	1765	428	1337	0.637
86	2837	2830	2834	1801	428	1373	0.654
99	2970	2971	2971	1938	498	1440	0.686
122	3132	3147	3140	2107	588	1519	0.723
141	3290	3310	3300	2268	698	1570	0.747
163	3375	3406	3391	2358	738	1620	0.771
178	3415	3450	3433	2400	748	1652	0.787
206	3520	3656	3543	2510	810	1700	0.810
231	3550	3615	3583	2550	823	1727	0.822
240	3542	3611	3577	2544	810	1734	0.826
250	3535	3608	3572	2539	790	1749	0.833
259	3550	3630	3590	2558	805	1753	0.835
275	3535	3625	3580	2548	808	1740	0.828
287	3570	3673	3622	2589	833	1756	0.836
294	3550	3657	3604	2571	818	1753	0.835
309	3552	3670	3611	2578	823	1755	0.833
322	3586	3710	3648	2615	858	1757	0.837
340	3611	3739	3675	2642	853	1789	0.852
354	3573	3719	3646	2614	845	1769	0.842
365	3613	3756	3684	2652	866	1786	0.850

Table A18

Elastic Properties

Mixture No.	Replacement Volume, %	w/c	Age at Loading, days	Sustained Load psi	Elastic Strain millionths	Elastic Modulus psi x 10^6
1	60	0.60	28	186	119	1.56
					156	1.19
						1.38
2	60	0.40	2	208	175	1.19
					162	1.28
						1.24
3	60	0.40	7	419	375	1.12
					330	1.27
						1.20
4	--	0.40	2	620	471	1.32
					458	1.35
						1.34
5	60	0.40	7	620	332	1.87
					354	1.75
						1.81
6	30	0.40	7	862	480	1.80
					414	2.08
						1.94
7	30	0.40	7	862	547	1.58
					540	1.60
						1.59
8	60	0.40	28	1129	546	2.07
					585	1.93
						2.00
9	--	0.60	28	1129	237	4.76
					259	4.36
						4.56
10	--	0.40	7	1129	722	1.56
					732	1.54
						1.55
11	--	0.40	7	1276	610	2.09
					616	2.07
						2.08
12	--	0.40	7	1276	754	1.69
					721	1.77
						1.73
13	--	0.40	7	1411	780	1.81
					705	2.00
						1.90

(Continued)

Table A18 (Concluded)

Mixture No.	Replacement Volume, %	w/c	Age at Loading, days	Sustained Load psi	Elastic Strain millionths	Elastic Modulus psi x 10^6
14	--	0.40	7	1411	734	1.92
					825	1.71
						1.82
15	60	0.25	2	1411	425	3.32
					468	3.01
						3.16
16	--	0.25	2	1698	540	3.14
					607	2.80
						2.97
17	--	0.40	28	2100	1080	1.94
					985	2.13
						2.04

Table A19

Calculated Creep Strains

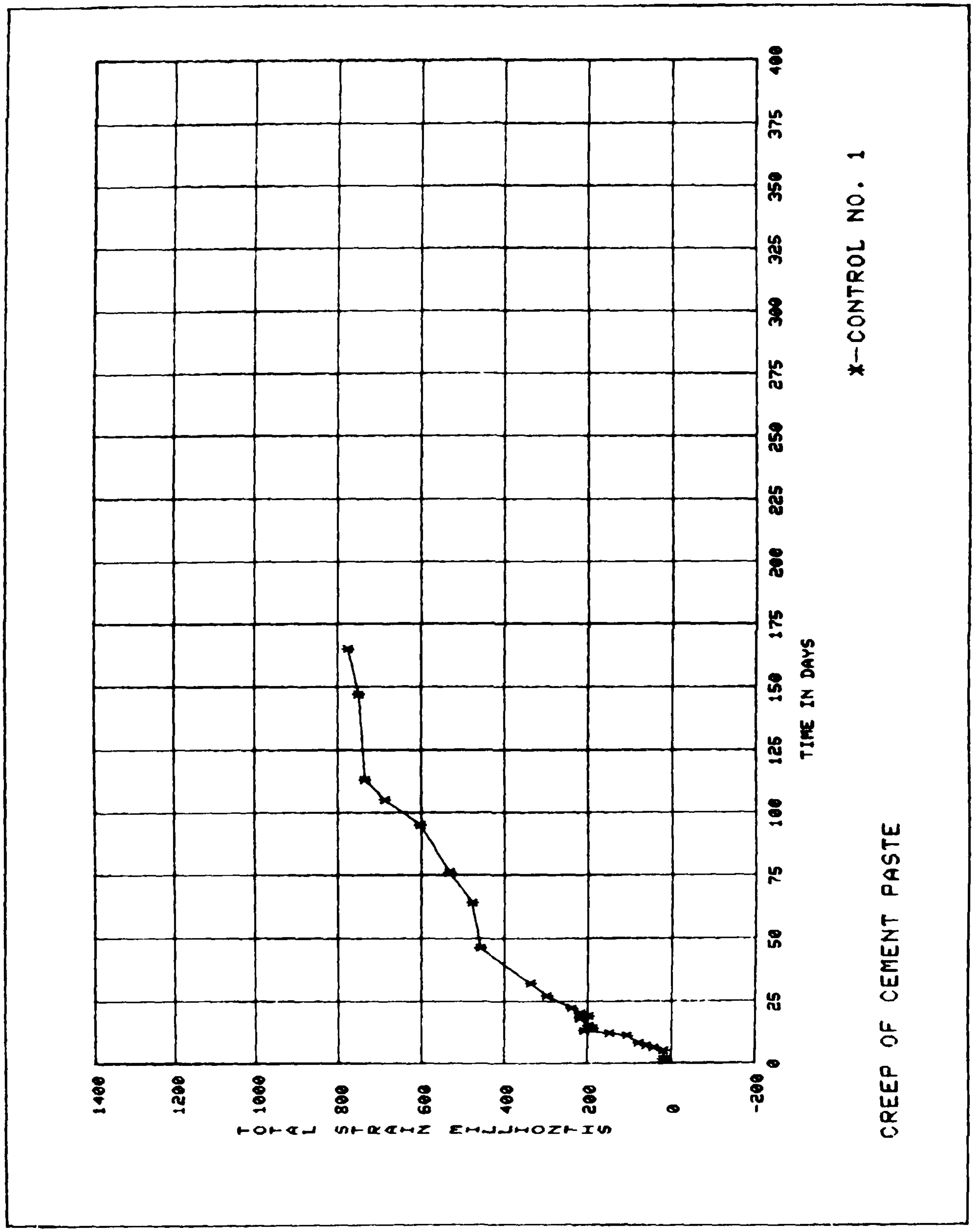
Mixture No.	Observations No.	Observations Span days	Equation Coefficients A	Equation Coefficients B	Index of Determination	Calculated Creep, 1 yr millionths/psi
1	25	165	*	*	*	*
2	32	181	0.3720	0.5377	0.875	3.5444
3	44	184	0.1468	0.2383	0.900	1.5527
4	48	204	0.2517	0.2286	0.786	1.6004
5	51	266	0.1528	0.2220	0.927	1.4626
6	43	299	0.1214	0.1688	0.926	1.1173
7	43	299	0.1122	0.1827	0.943	1.1960
8	47	366	-0.0744	0.1520	0.967	0.8224
9	34	278	-0.0011	0.0568	0.992	0.3340
10	47	366	0.1332	0.1729	0.931	1.1533
11	53	365	0.0373	0.1515	0.982	0.9311
12	54	365	0.1641	0.1658	0.903	1.1423
13	50	366	0.1406	0.1814	0.941	1.2108
14	50	366	0.1270	0.1432	0.906	0.9719
15	50	366	0.1409	0.1515	0.922	1.0347
16	44	365	0.0807	0.1207	0.955	0.7928
17	44	365	-0.0200	0.1502	0.996	0.8662

* Wide variations in data precluded curve fitting.

Table A20

Summary of Results

Mixture No.	Cement Type	Replacement Material No.	Replacement Material Vol., %	W/C	Loading Age days	Elastic Modulus psi x 10^6	Calculated Creep - 1 yr millionths/psi
1	688(3)	510	60	0.60	28	1.38	--
2	688(3)	510	60	0.40	2	1.24	3.5444
3	688(3)	507	60	0.40	7	1.20	1.5527
4	688(3)	--	--	0.40	2	1.34	1.6004
5	688(3)	510	60	0.40	7	1.81	1.4626
6	688(3)	510	30	0.40	7	1.94	1.1173
7	688(3)	507	30	0.40	7	1.59	1.1960
8	688(3)	510	60	0.40	28	2.00	0.8224
9	688(3)	--	--	0.60	28	4.56	0.3340
10	735(IP)	--	--	0.40	7	1.55	1.1533
11	772(II)	--	--	0.40	7	2.08	0.9311
12	742(IP)	--	--	0.40	7	1.73	1.1423
13	752(IS)	--	--	0.40	7	1.90	1.2108
14	688(3)	--	--	0.40	7	1.82	0.9719
15	688(3)	510	60	0.25	2	3.16	1.0347
16	688(3)	--	--	0.25	2	2.97	0.7928
17	688(3)	--	--	0.40	28	2.04	0.8662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75
100
125
150
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200
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250
275
300
325
350
375
400
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0
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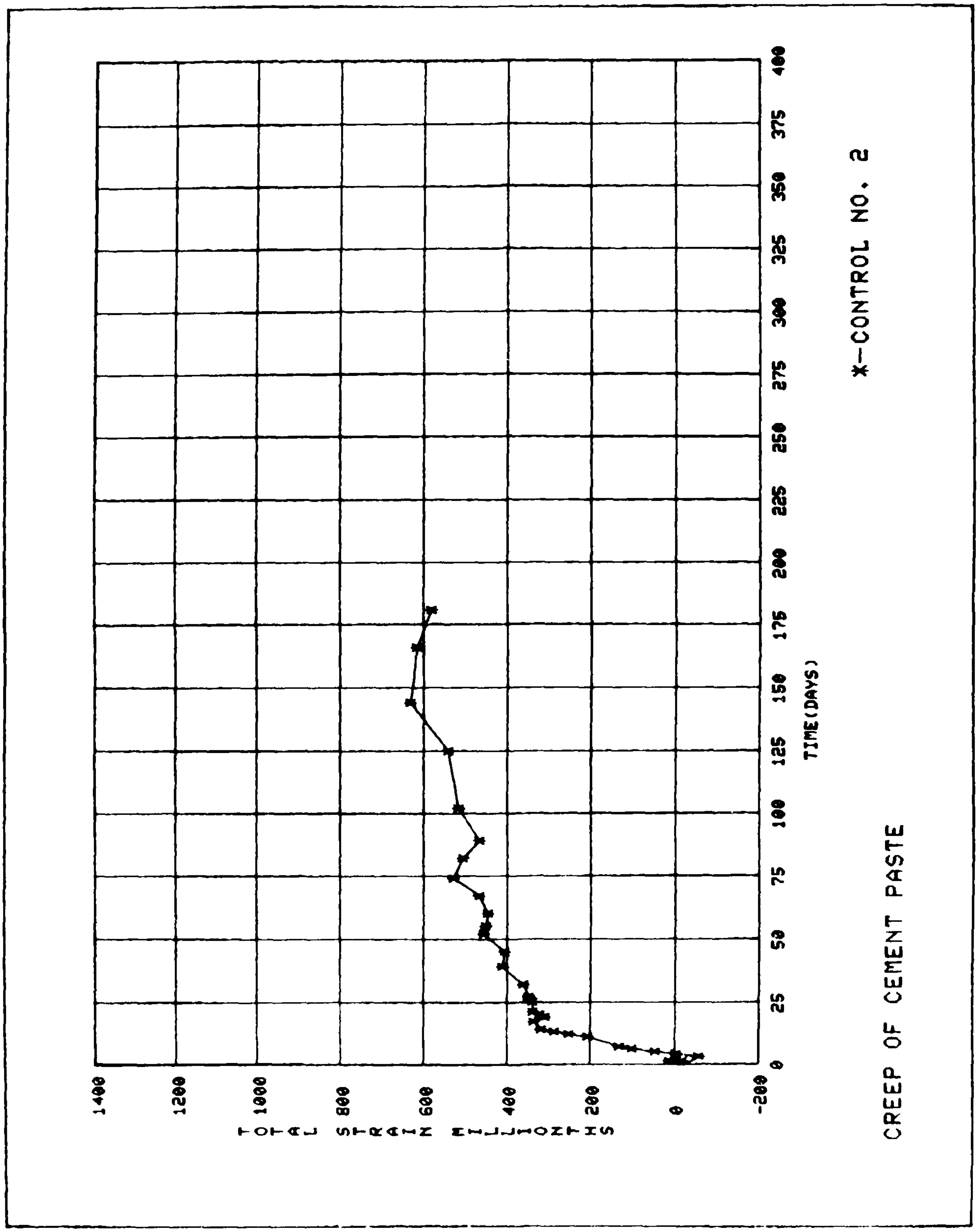

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TOTAL STRAIN MILLIONTHS
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1000
800
600
400
200
0
-200
TIME(DAYS)
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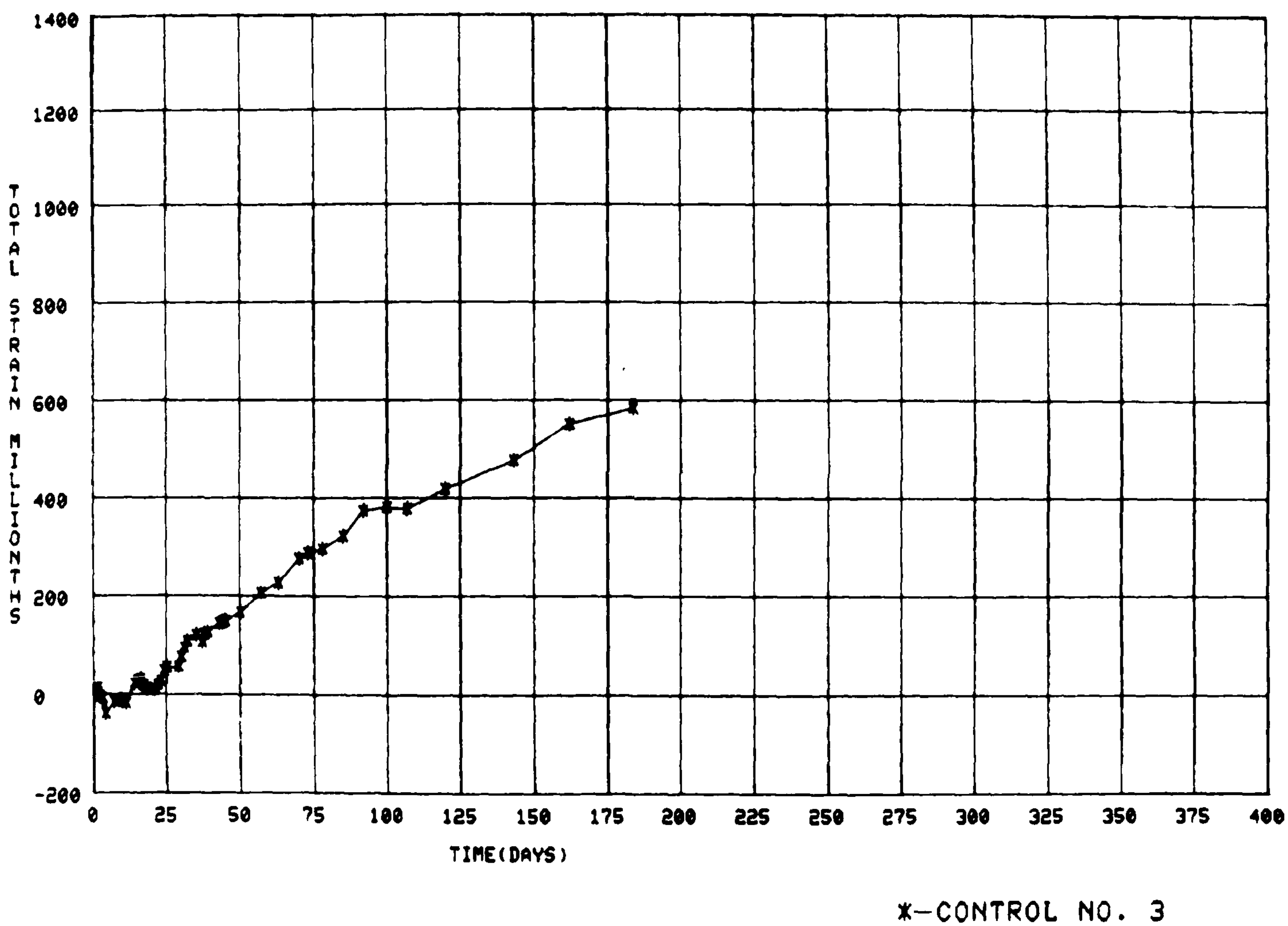
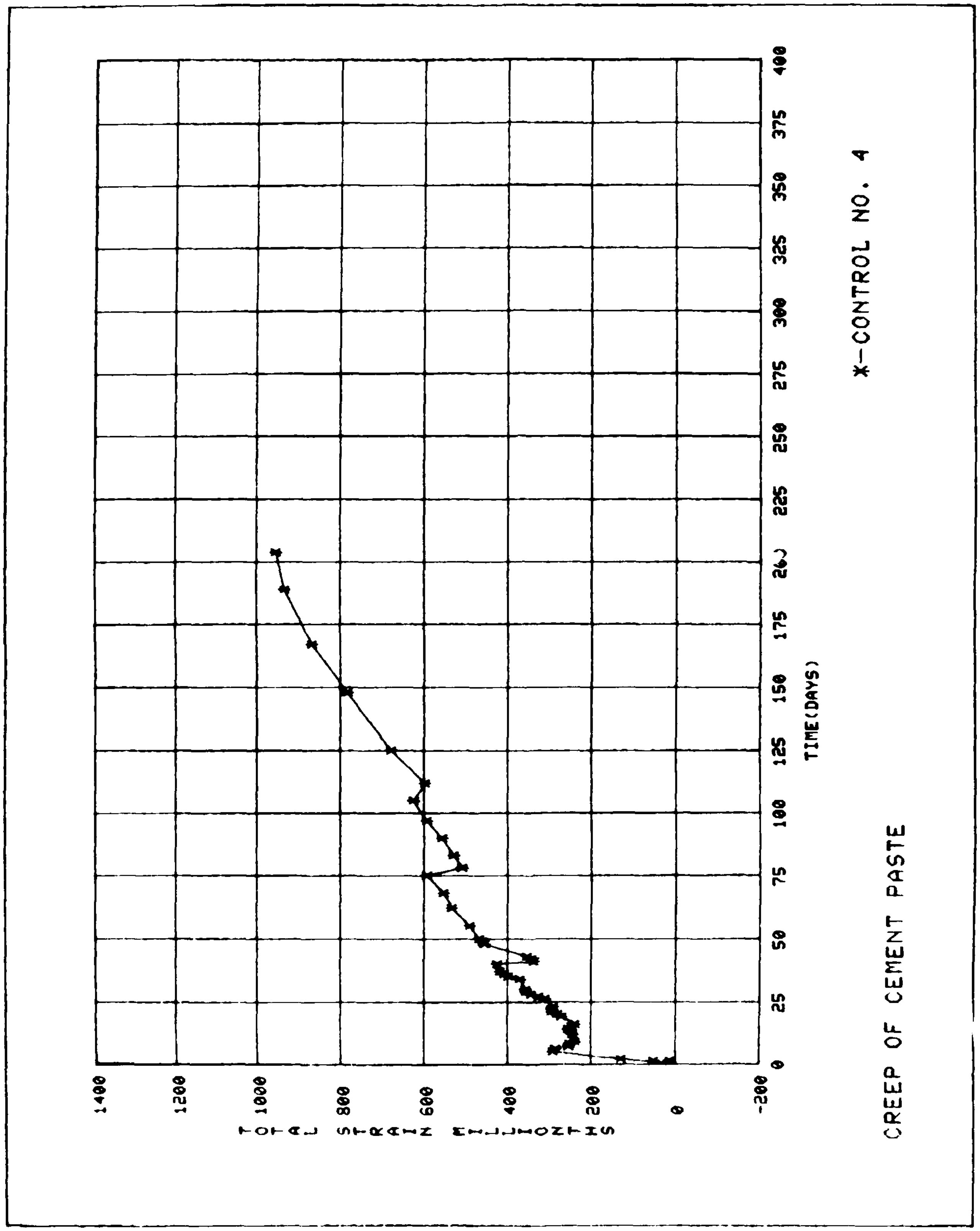
75
100
125
150
175
200
225
250
275
300
325
350
375
400

PLATE A2



CREEP OF CEMENT PASTE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TIME(DAYS)
TOTAL STRAIN MILLIONTHS
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75
100
125
150
175
200
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325
350
375
400
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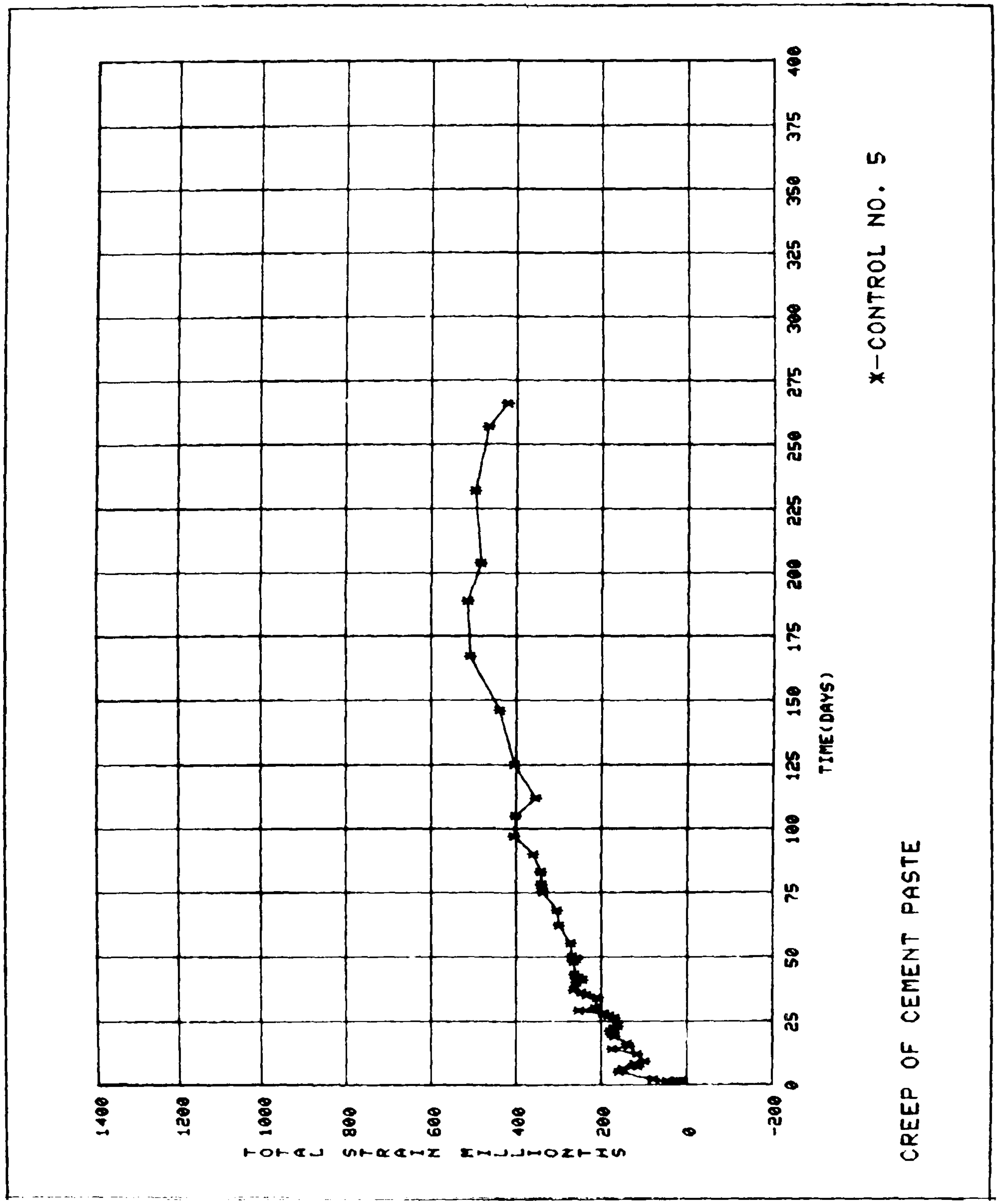
0
200
400
600
800
1000
1200
1400

PLATE A4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TOTAL STRAIN MILLIONTHS
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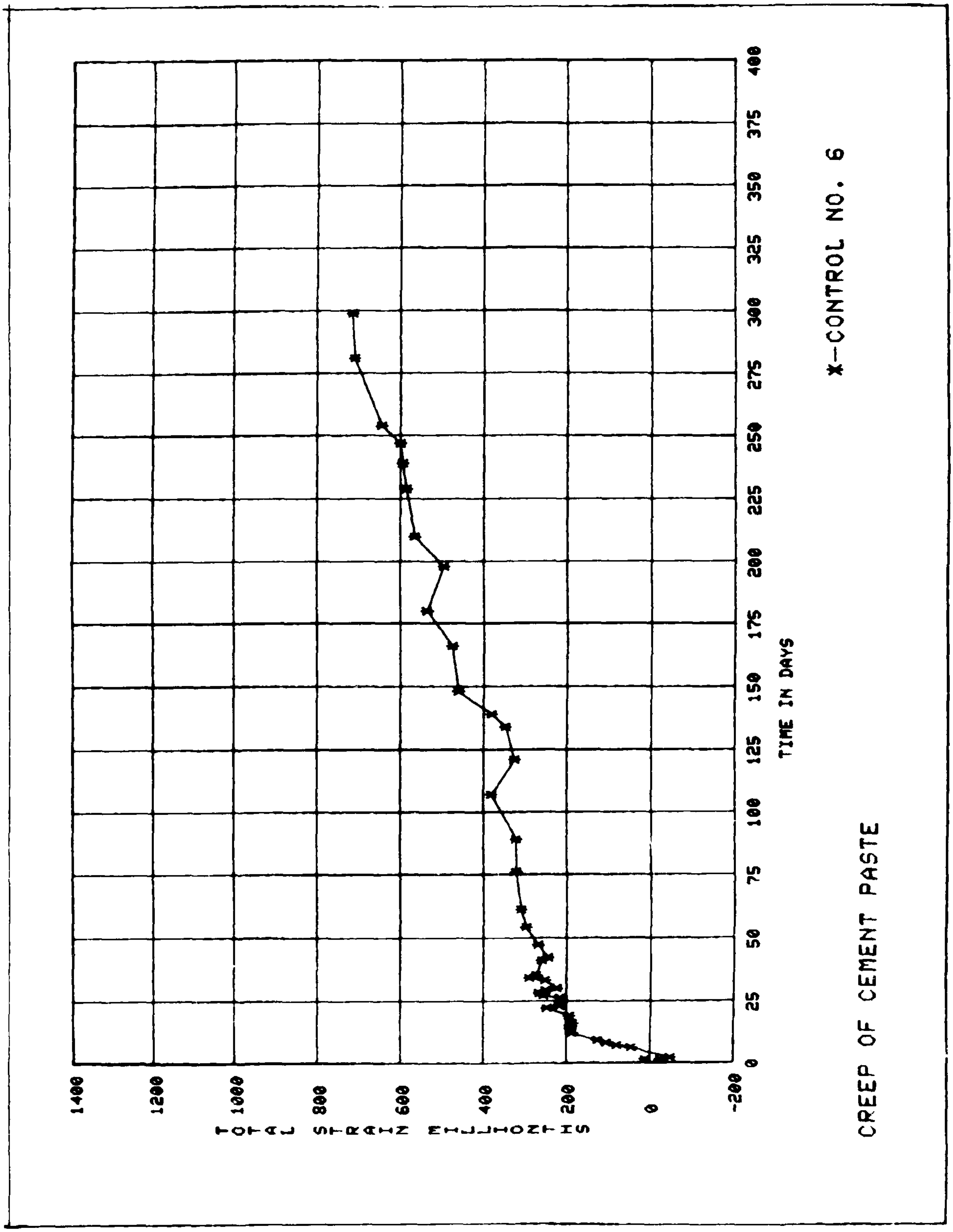
100
125
150
175
200
225
250
275
300
325
350
375
400
1400
1200
1000
800
600
400
200
0
-200

PLATE A5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TOTAL STRAIN MILLIONTHS
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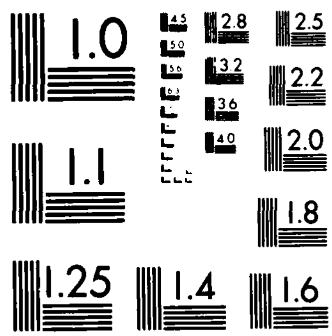
100
125
150
175
200
225
250
275
300
325
350
375
400
-200
0
200
400
600
800
1000
1200
1400

PLATE A6

AD-A171 753 VARIATIONS IN CEMENTITIOUS MEDIA(U) ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS STRUCTURES LAB R E REINHOLD ET AL. MAY 86 WES/TR/SL-86-10 2/3

UNCLASSIFIED F/G 11/2 NL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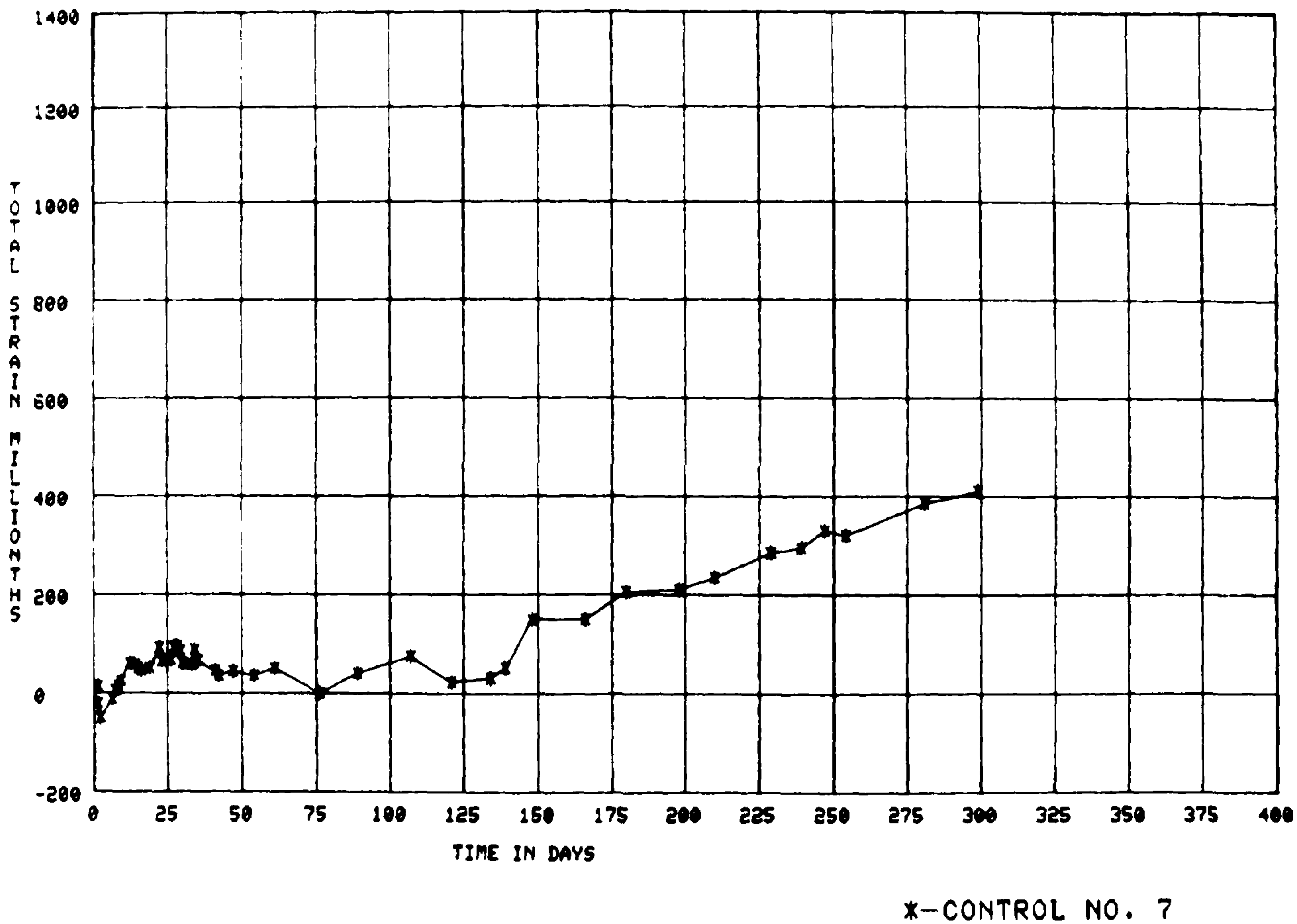

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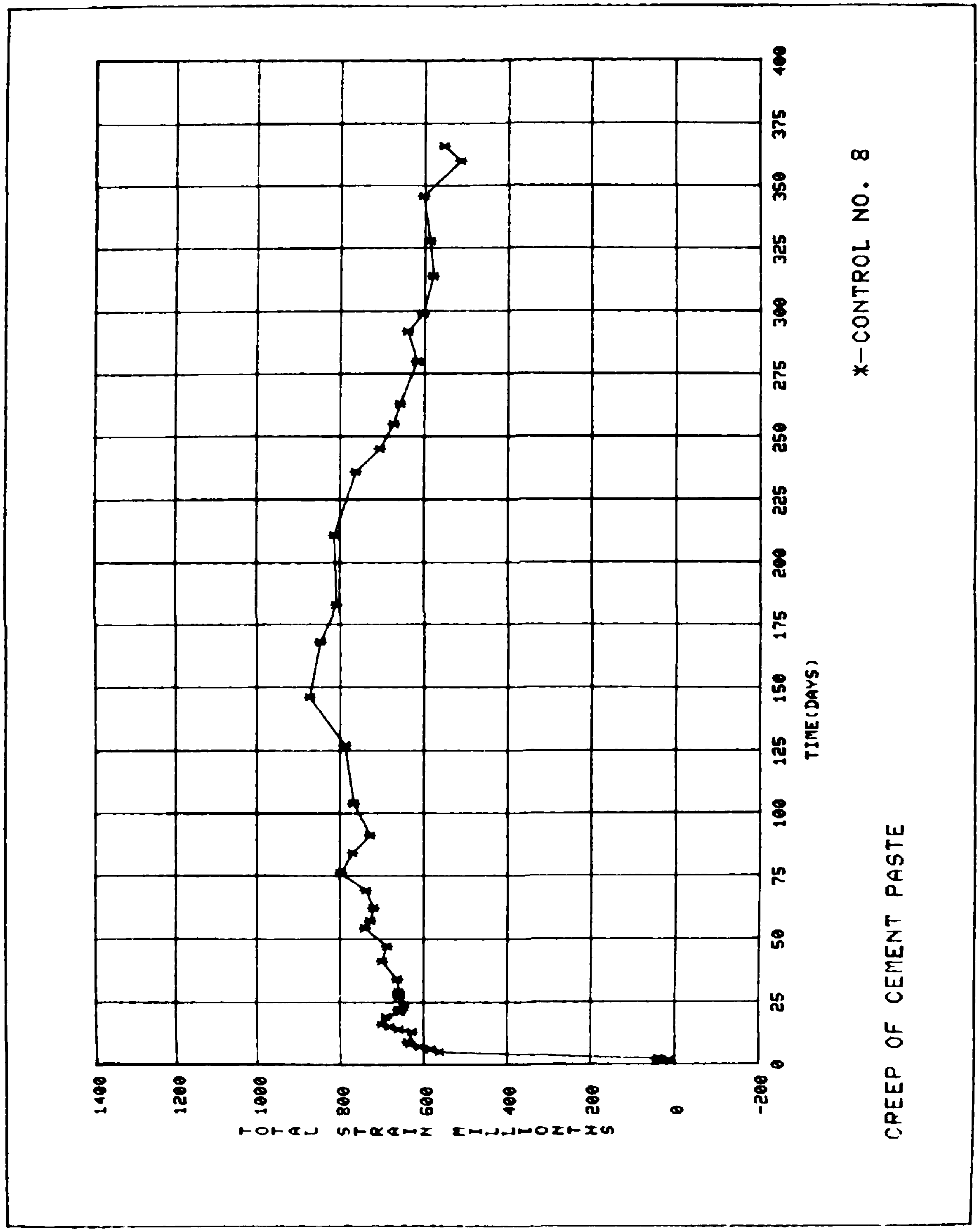
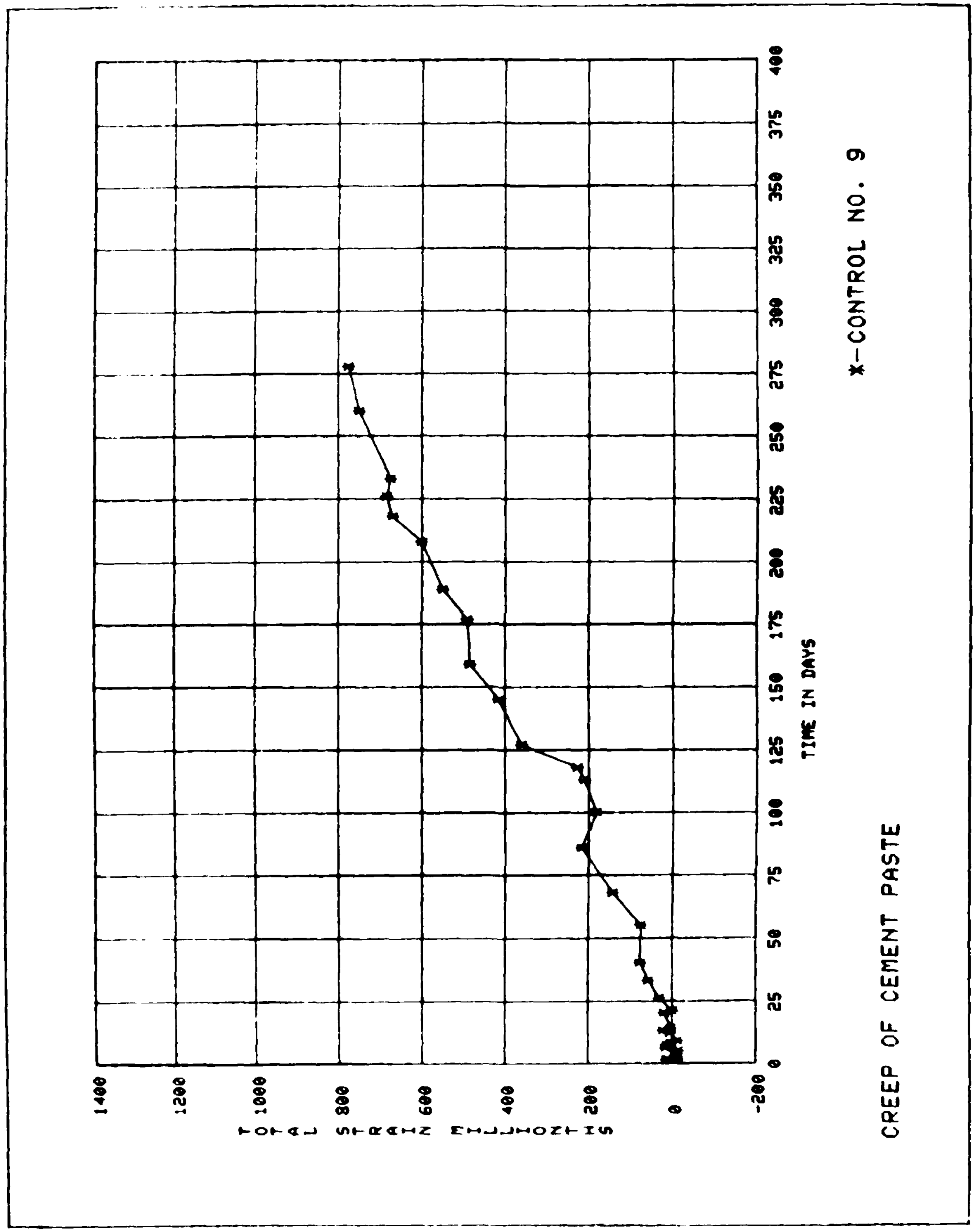


CREEP OF CEMENT PASTE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CREEP OF CEMENT PASTE
TIME IN DAYS
TOTAL STRAIN MILLIONTHS
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75
100
125
150
175
200
225
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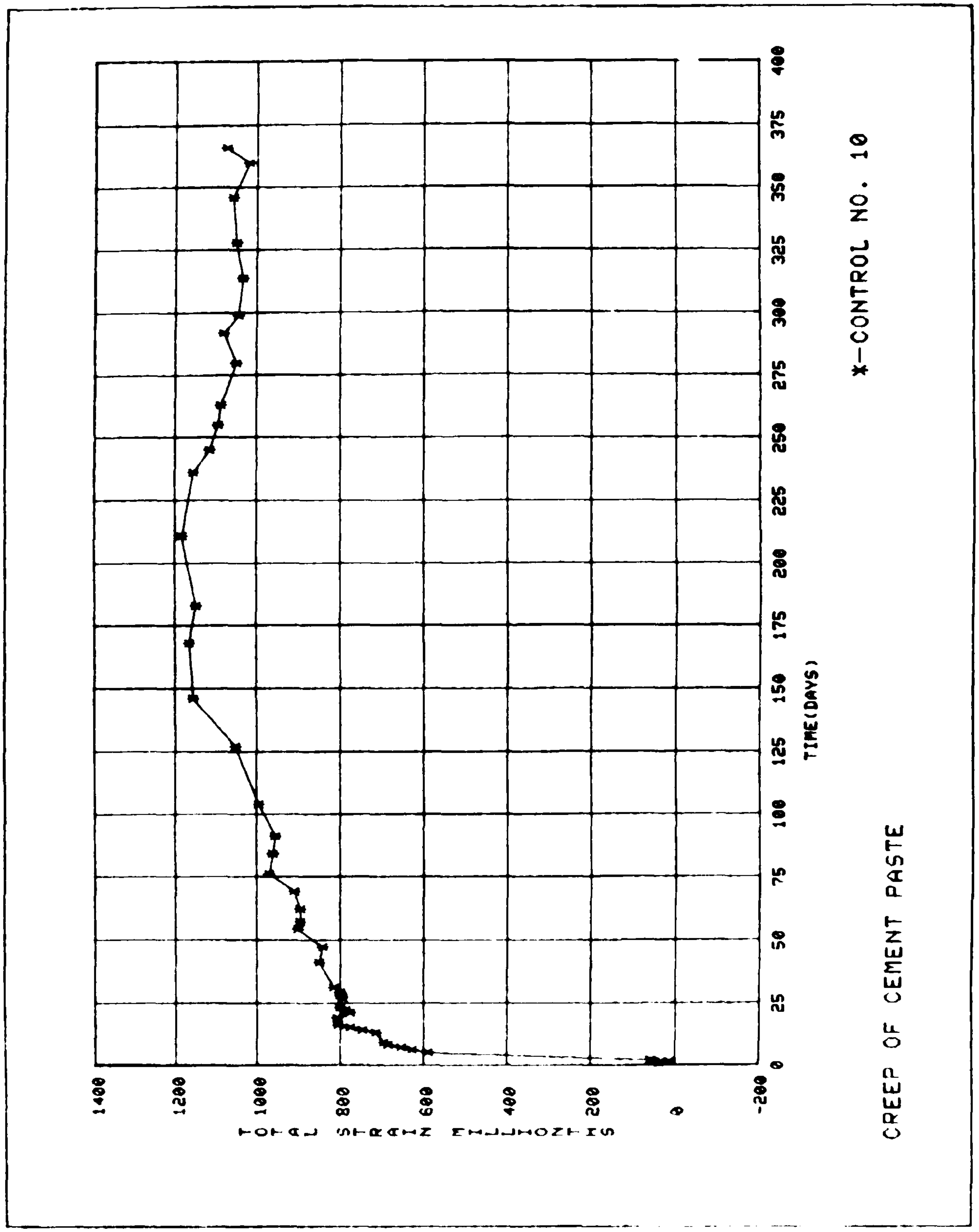
275
300
325
350
375
400
1400
1200
1000
800
600
400
200
0
-200

PLATE A9



CREEP OF CEMENT PASTE
*—CONTROL NO. 10
TIME(DAYS)
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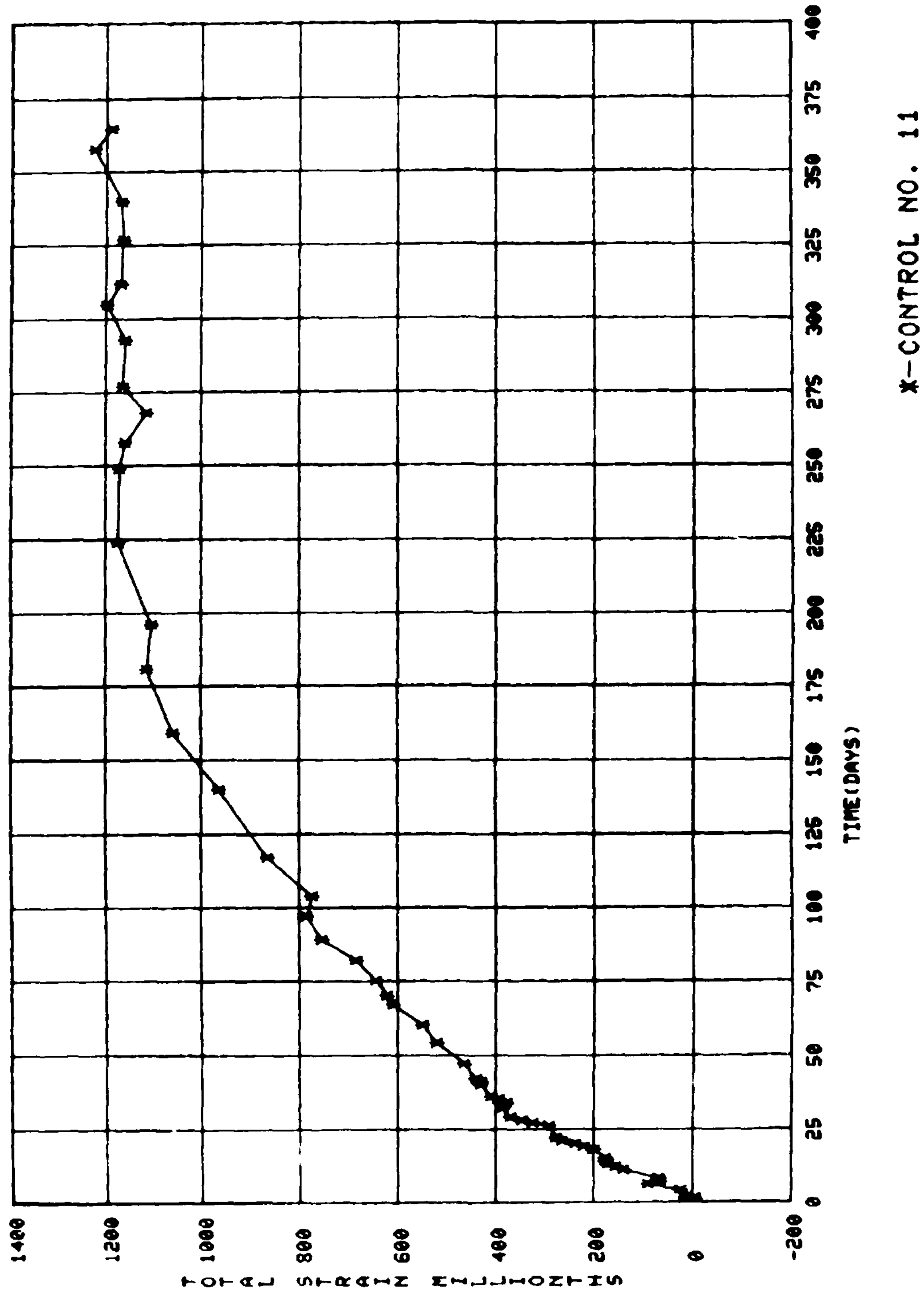
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
-200
0
200
400
600
800
1000
1200
1400

PLATE A10



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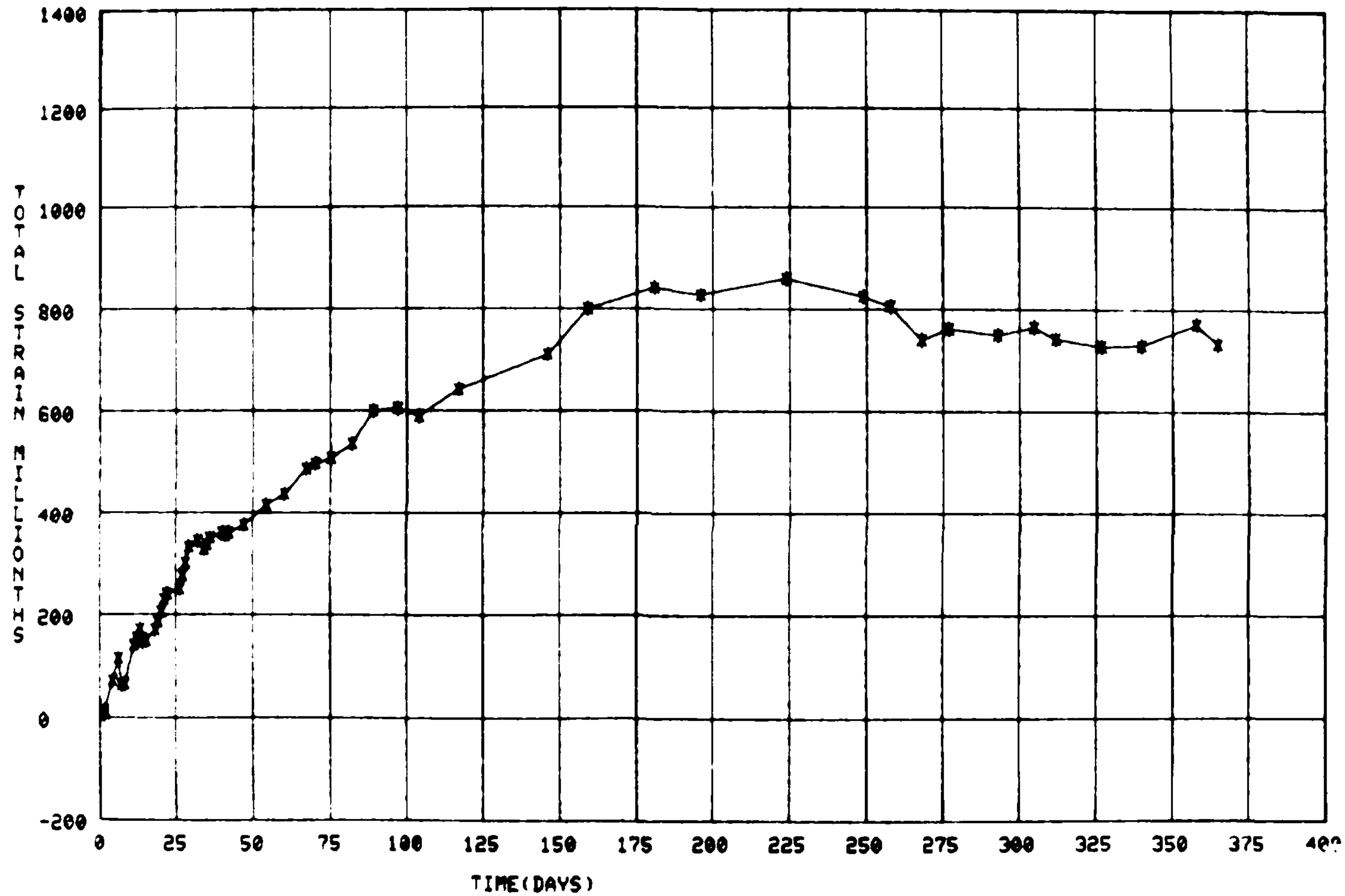

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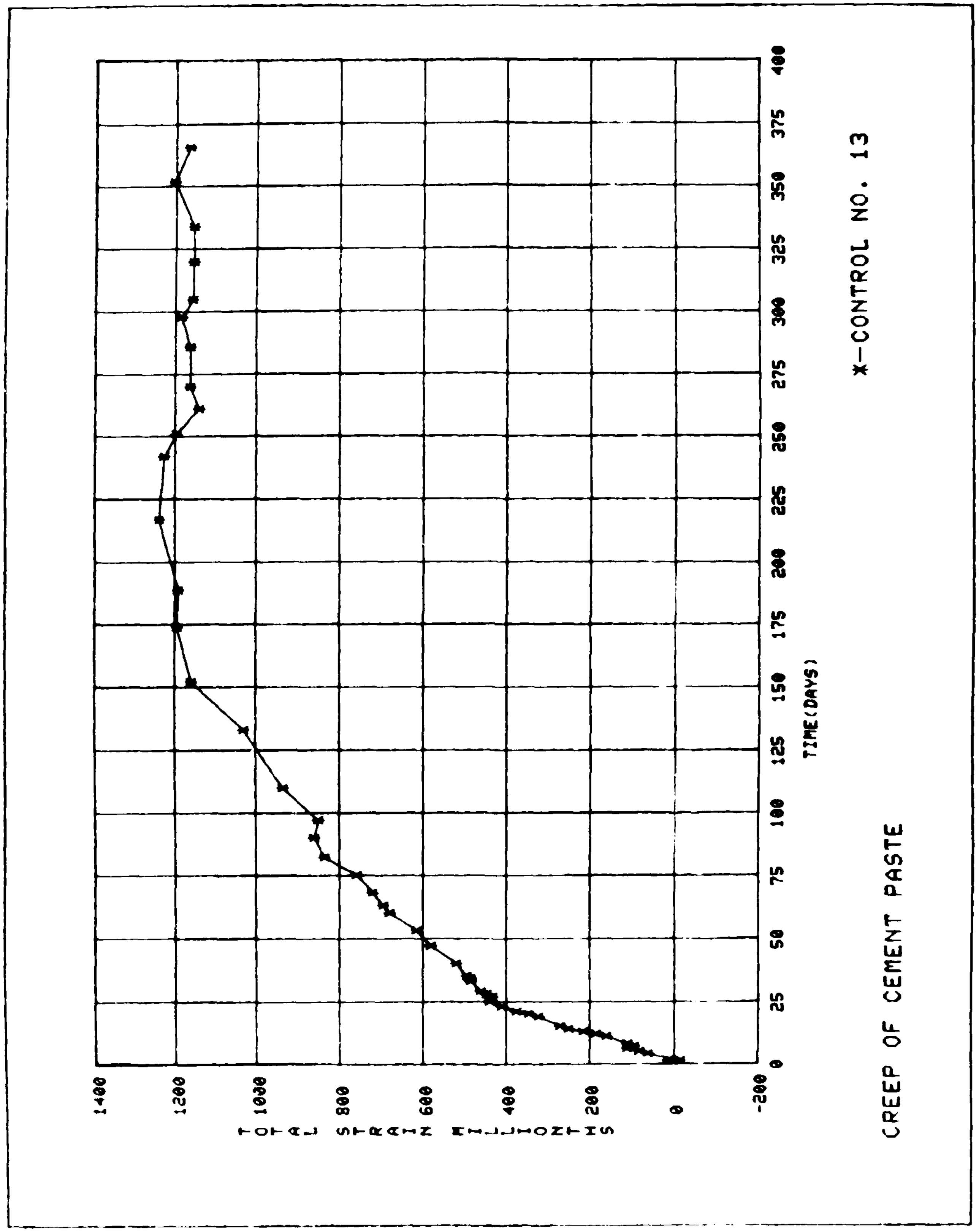
CREEP OF CEMENT PASTE


CREEP OF CEMENT PASTE
X-CONTROL NO. 13
TOTAL STRAIN MILLIONTHS
TIME(DAYS)
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1200
1000
800
600
400
200
0
-200
0
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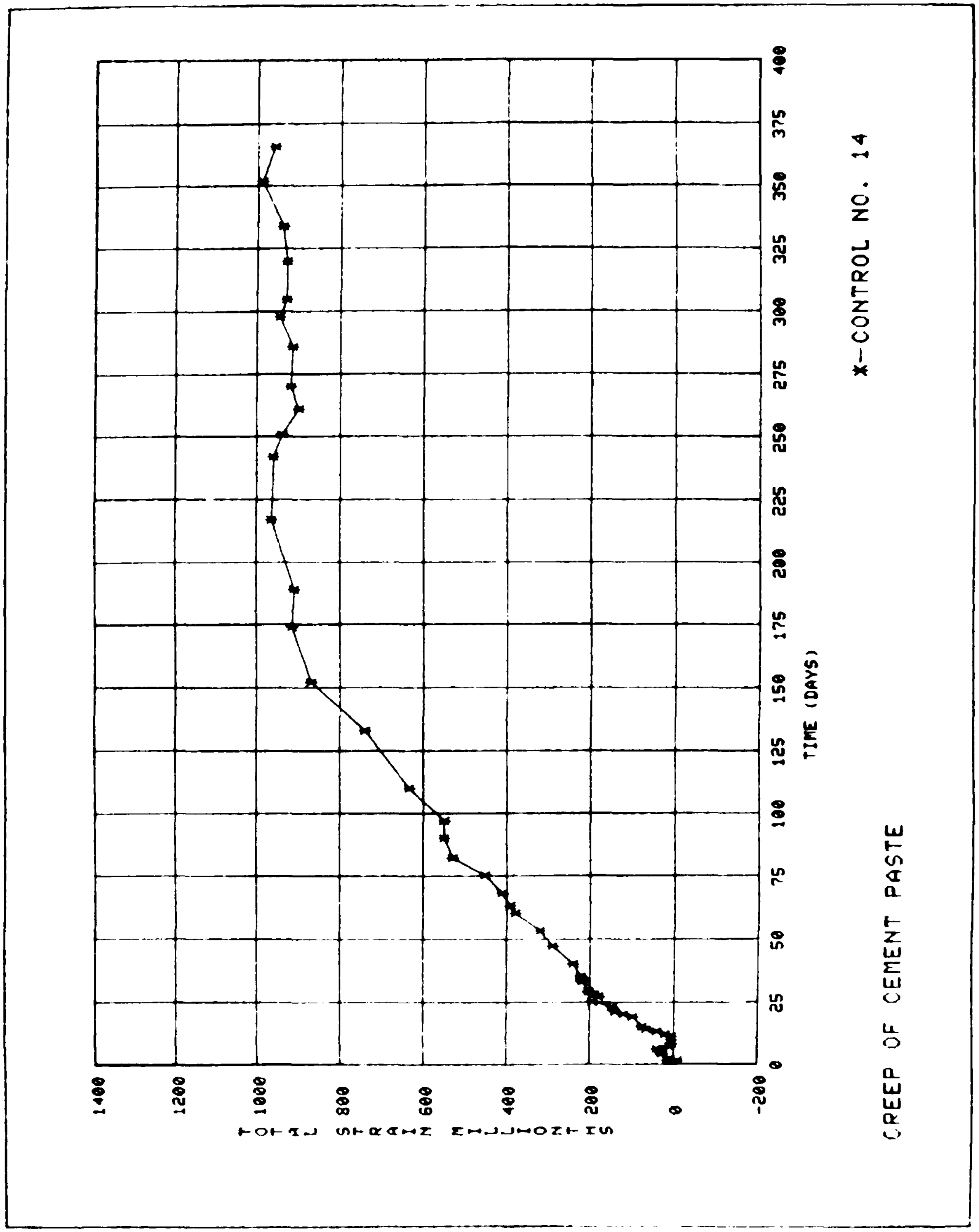
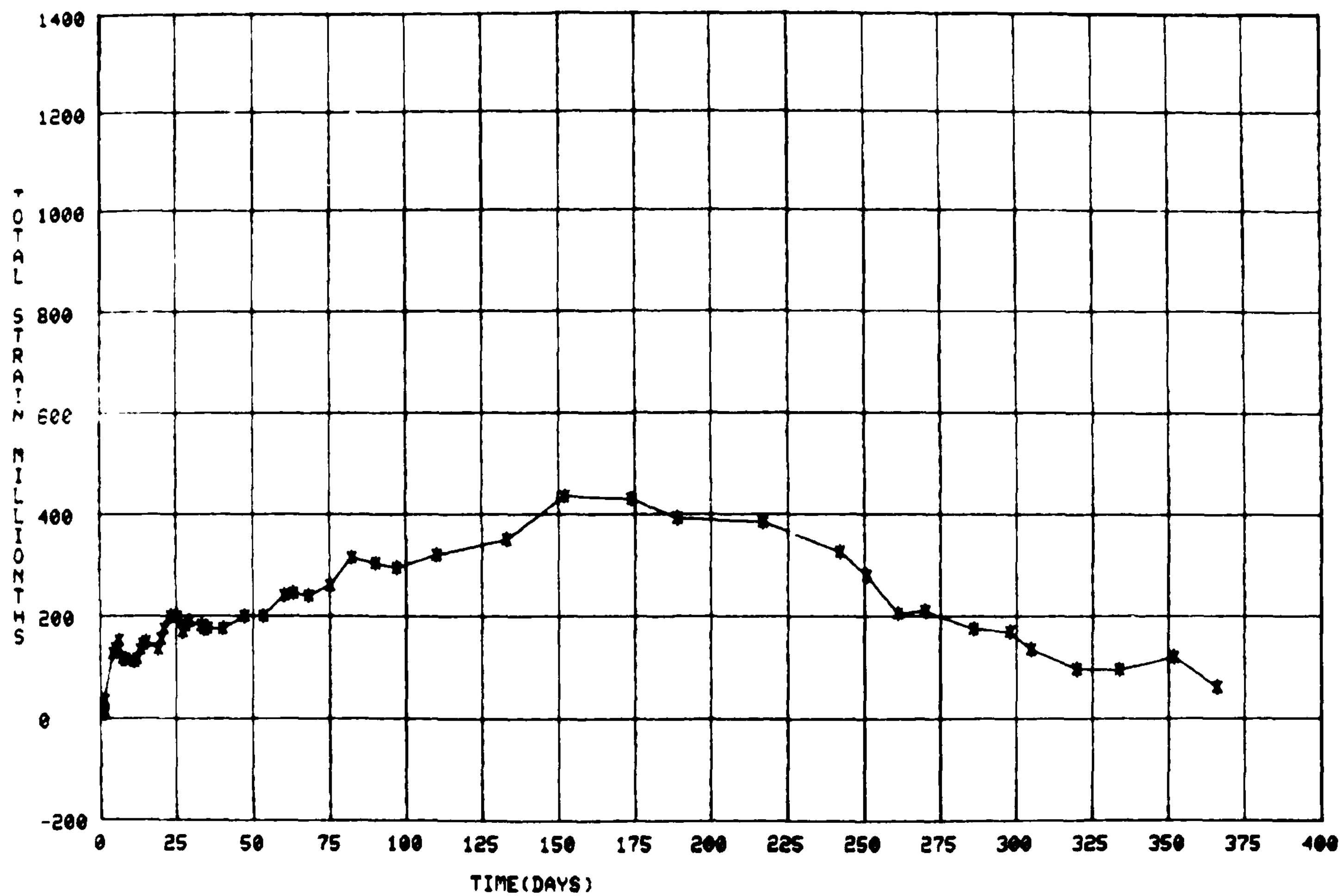
75
100
125
150
175
200
225
250
275
300
325
350
375
400

PLATE A13



CREEP OF CEMENT PASTE

PLATE A14



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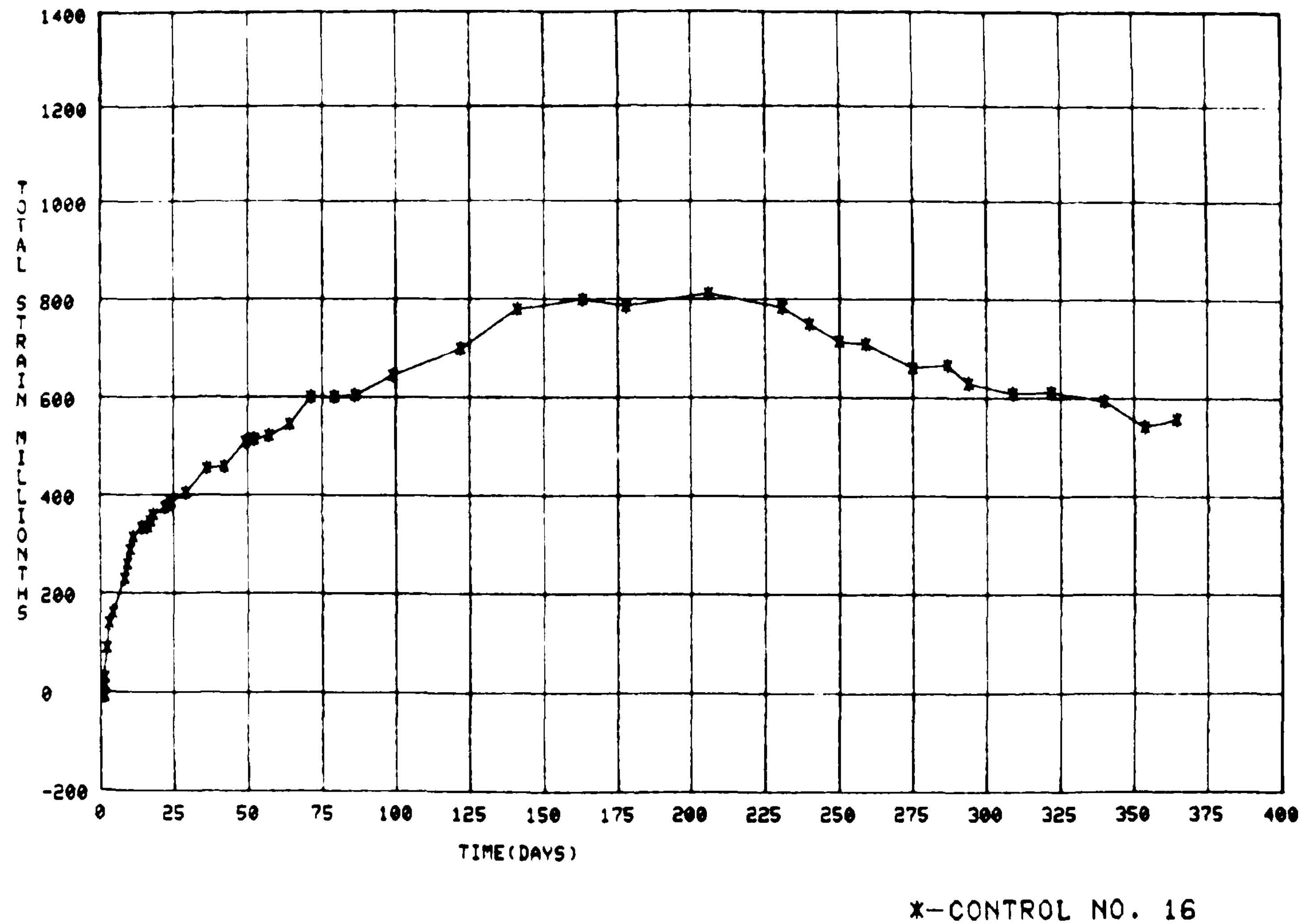
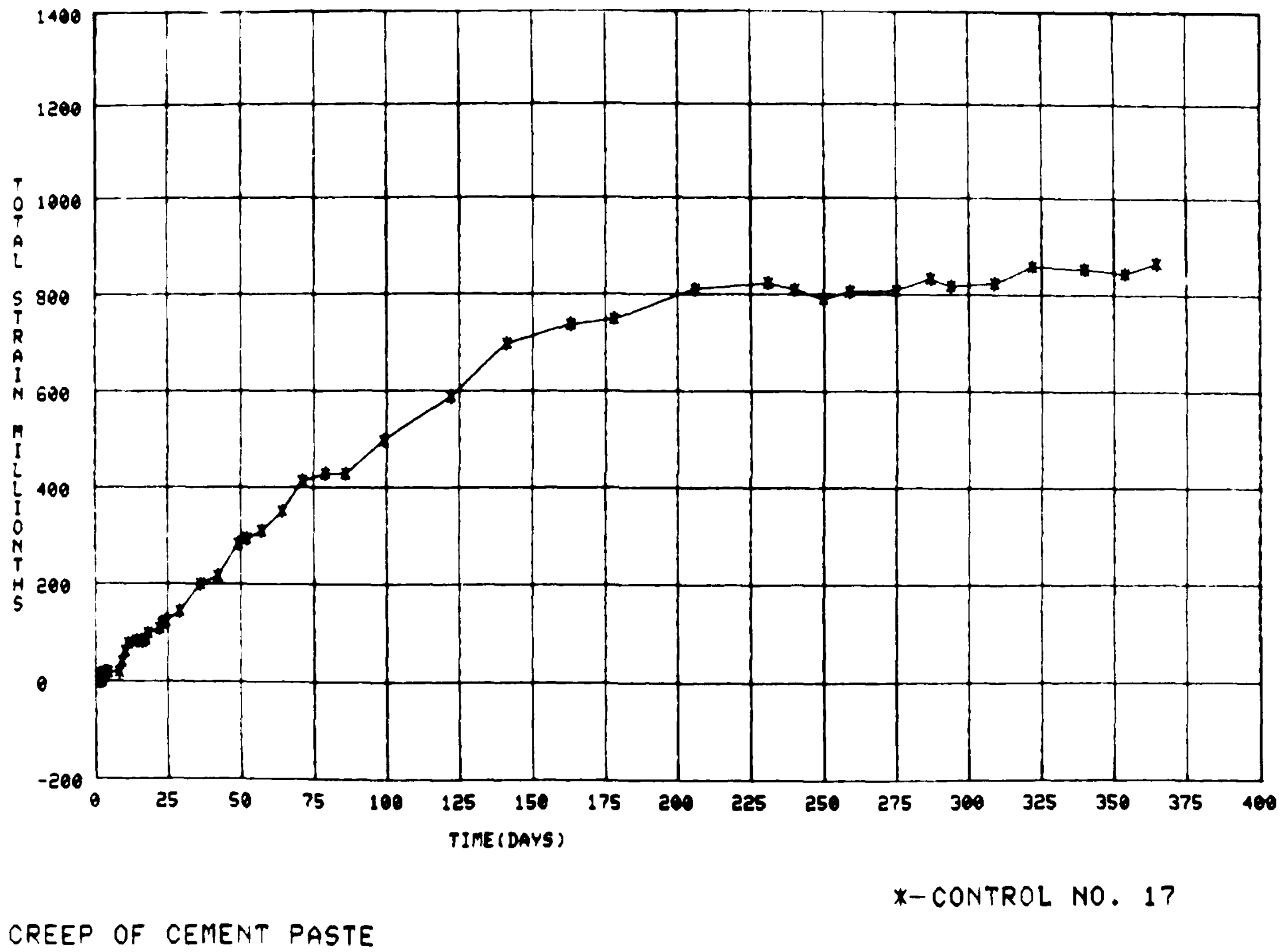
CREEP OF CEMENT PASTE

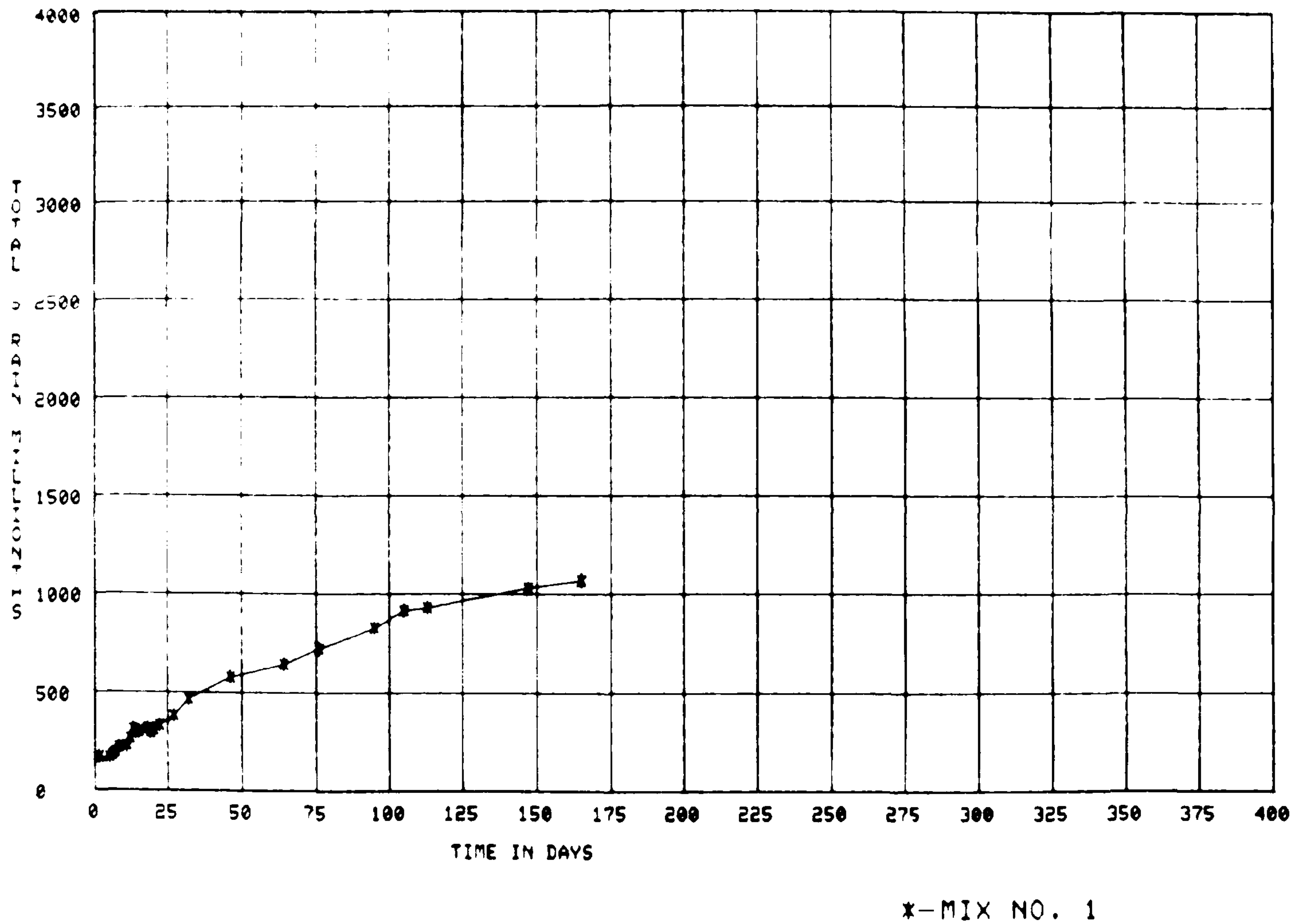


CREEP OF CEMENT PASTE

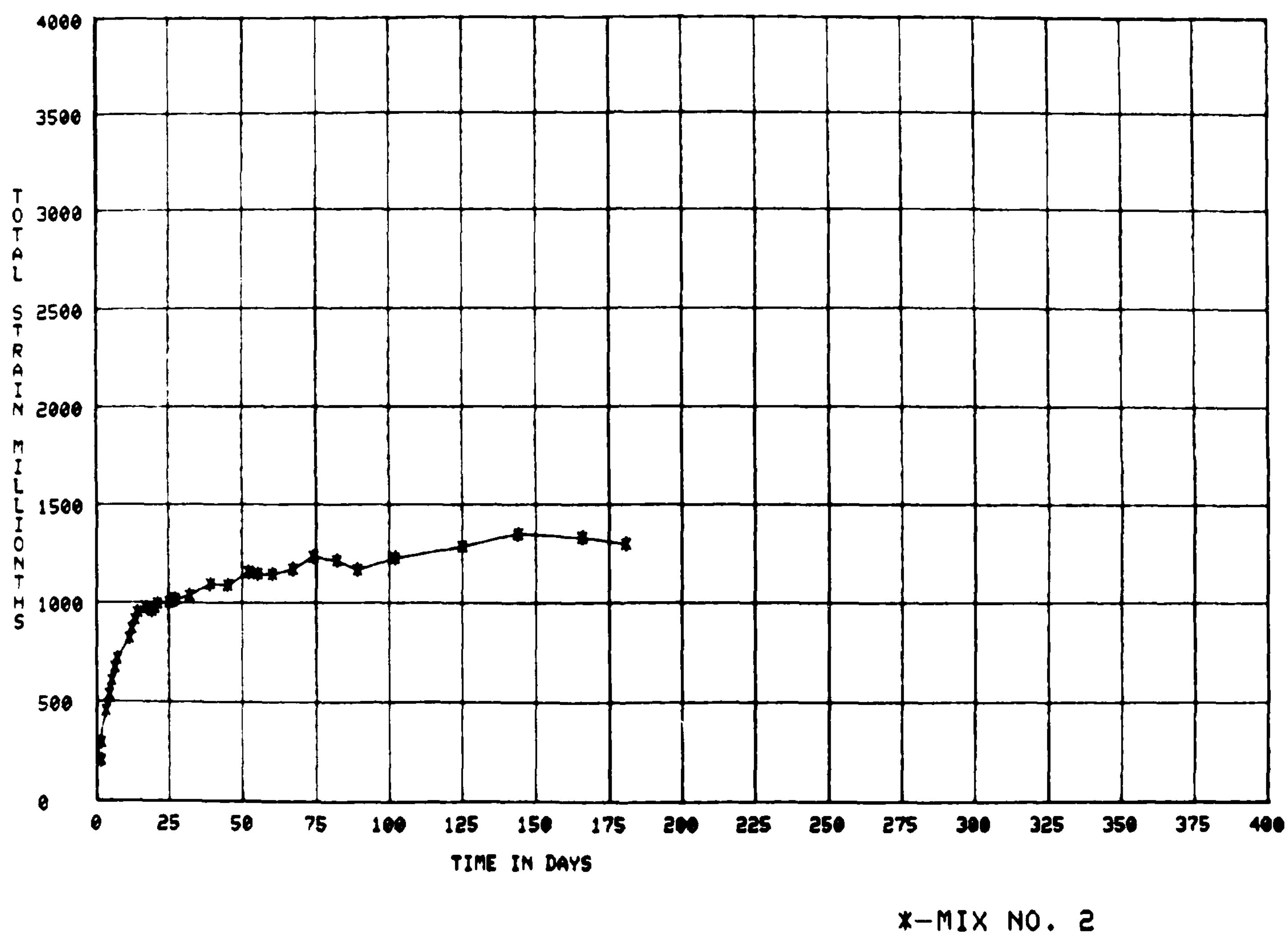
PLATE A16



1400
1200
1000
800
600
400
200
0
-200
TOTAL STRAIN MILLIONTHS
0
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
TIME(DAYS)
*-CONTROL NO. 17
CREEP OF CEMENT PASTE



CREEP OF CEMENT PASTE



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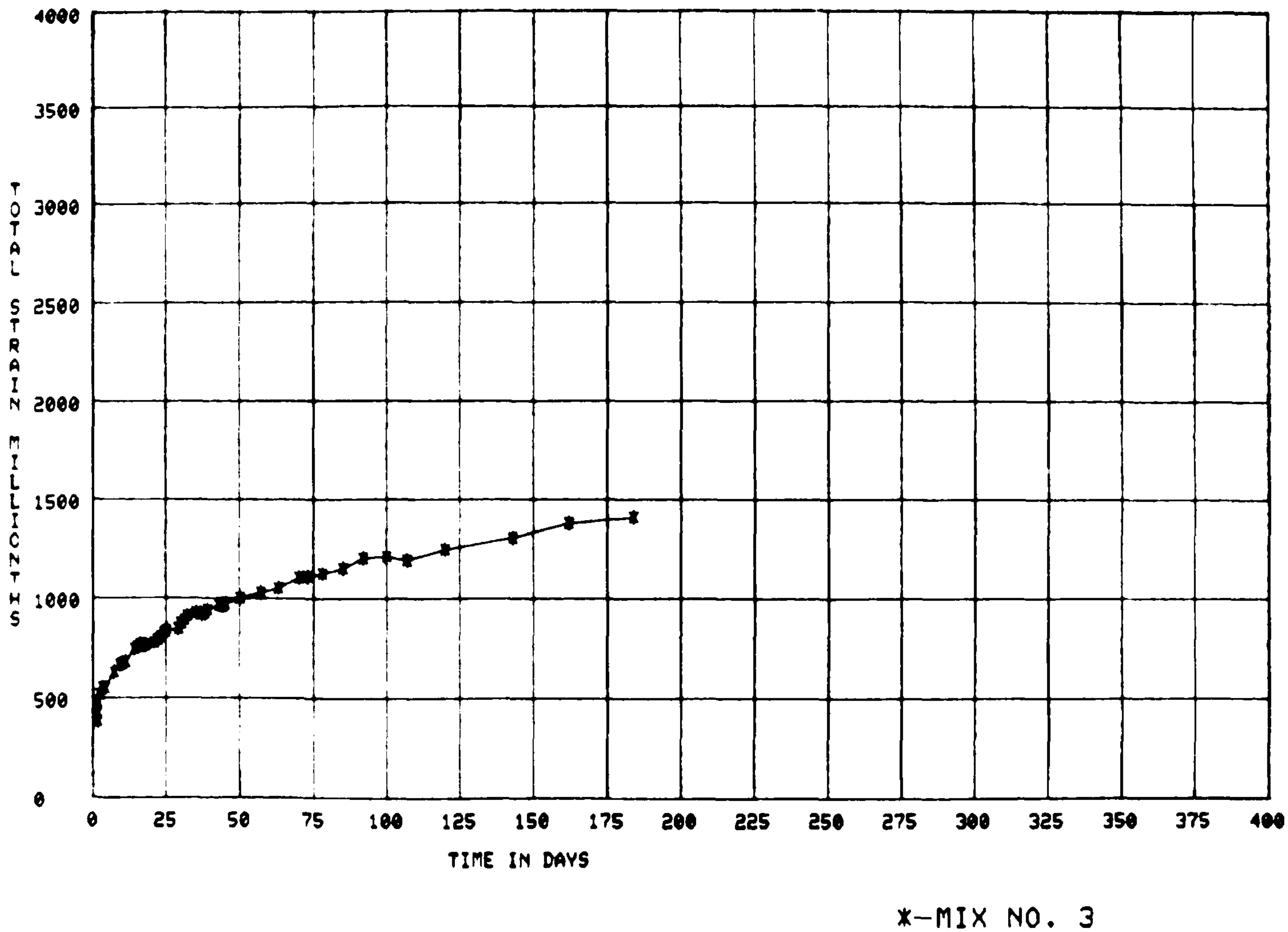
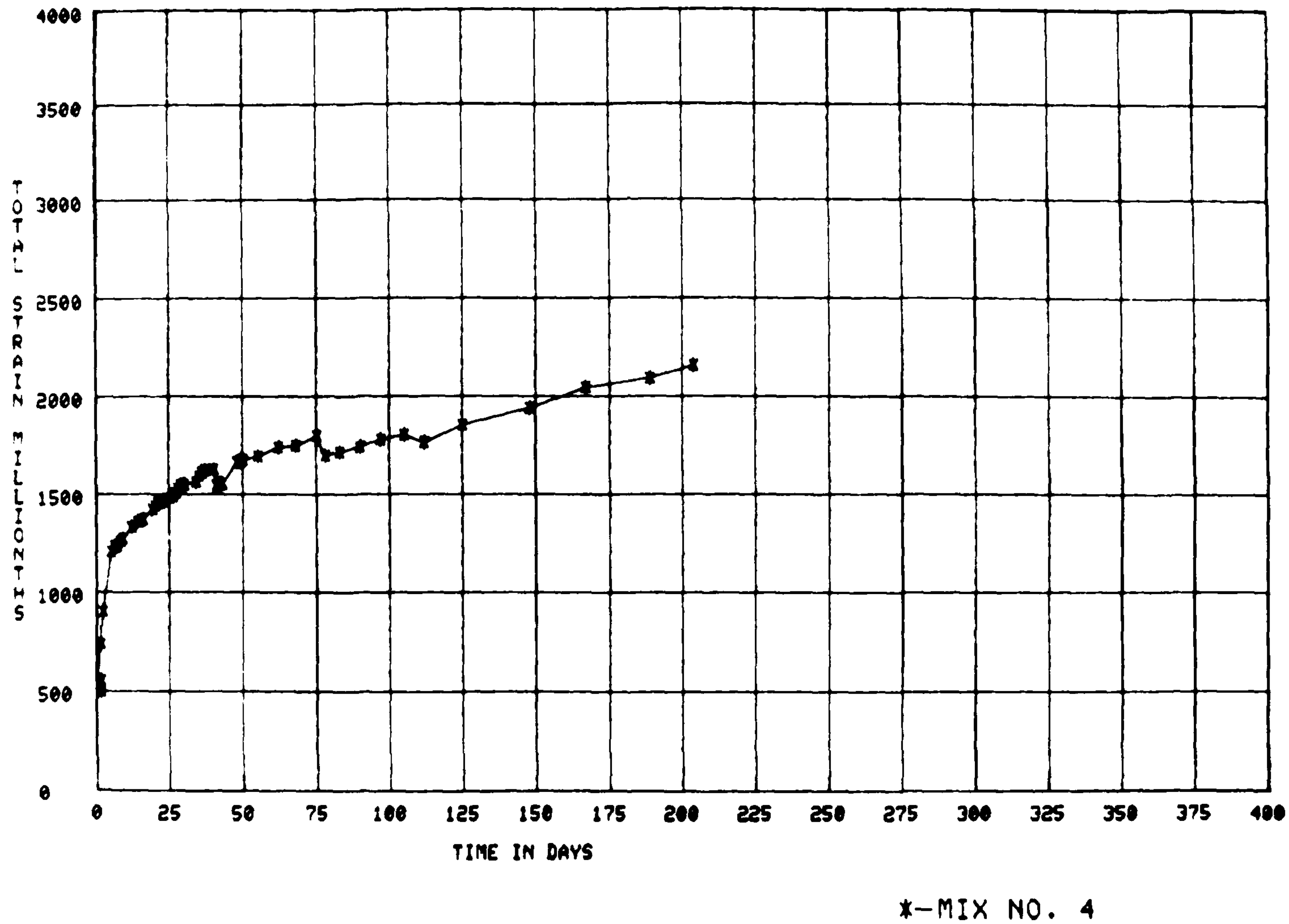


CREEP OF CEMENT PASTE



CREEP OF CEMENT PASTE

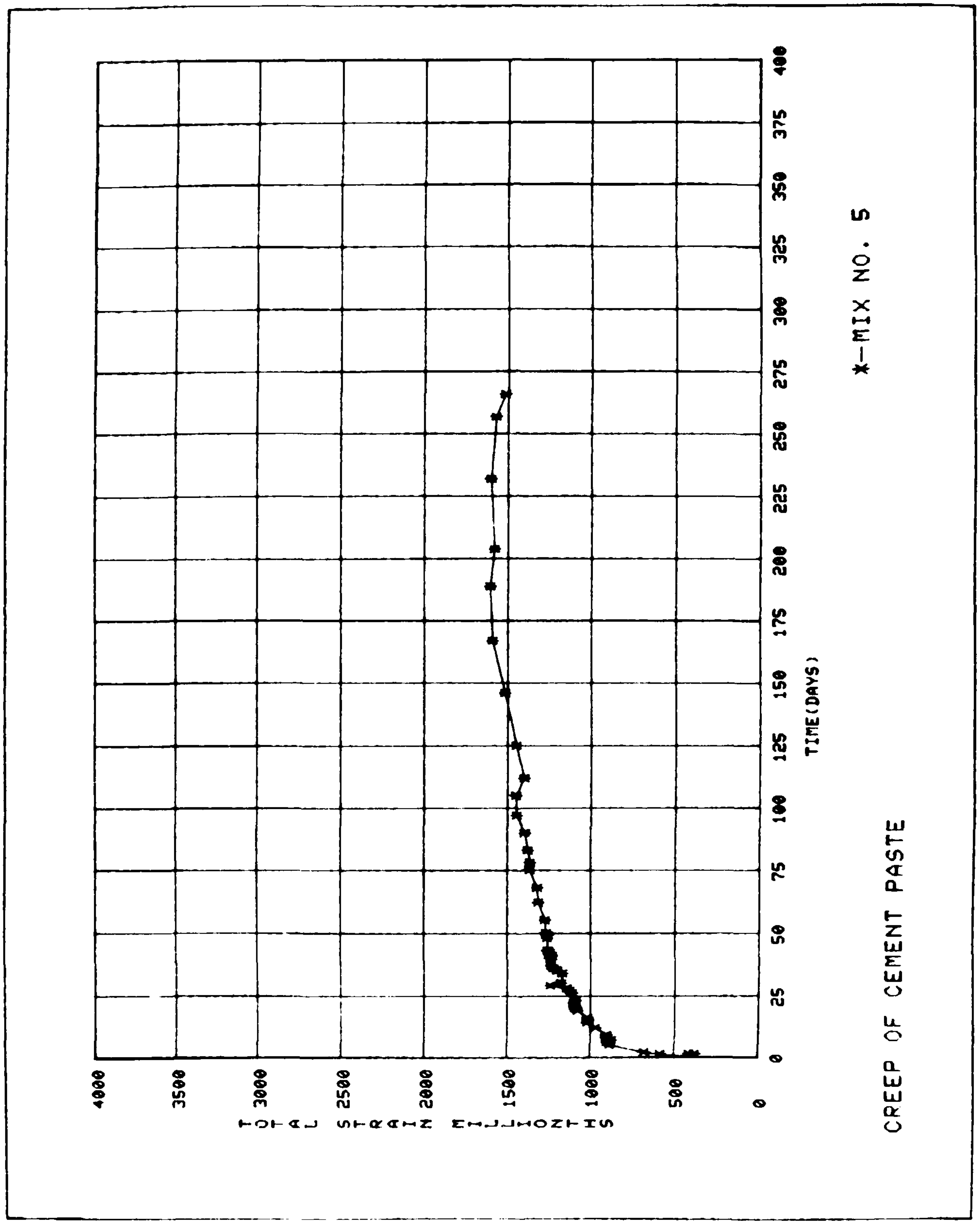
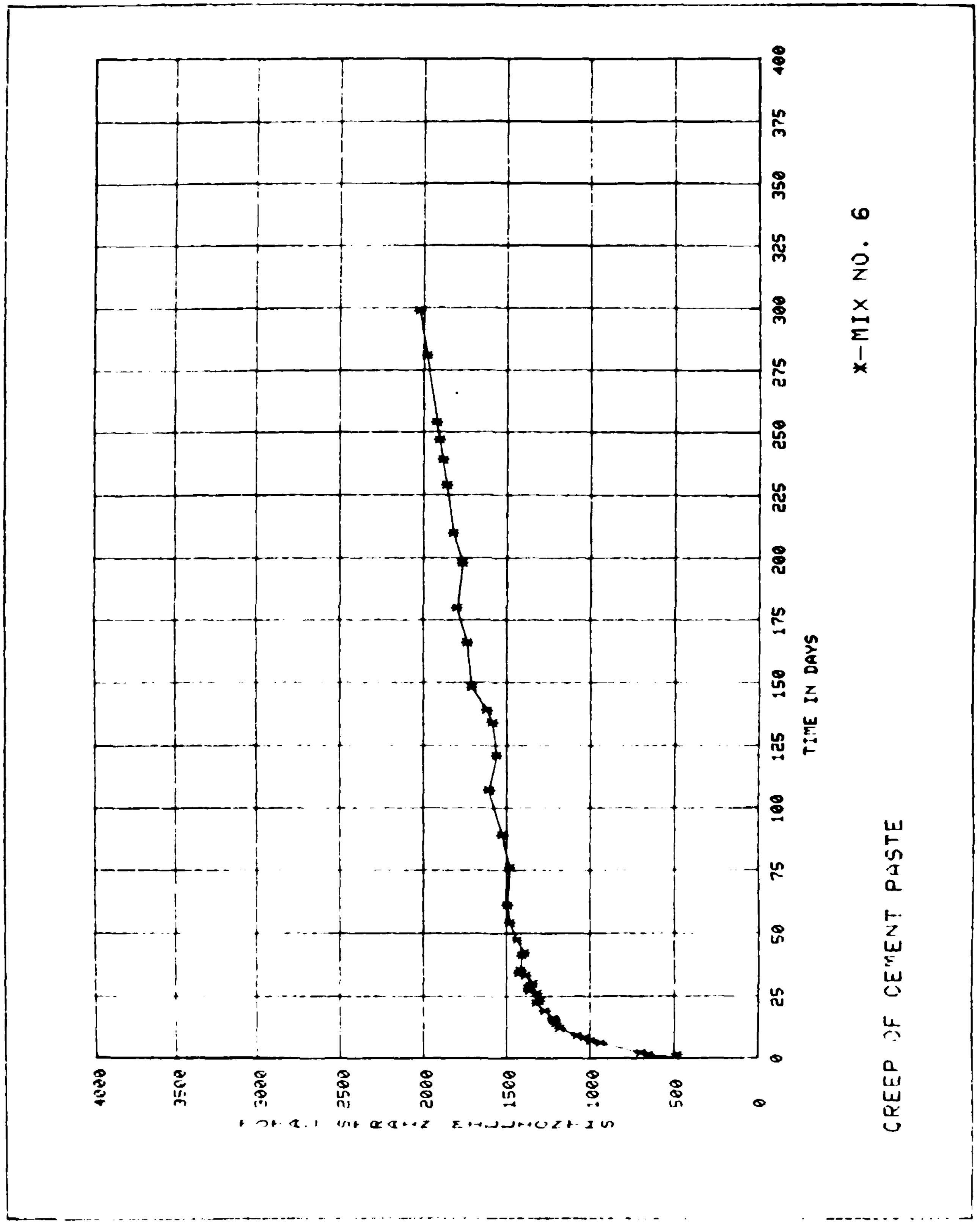
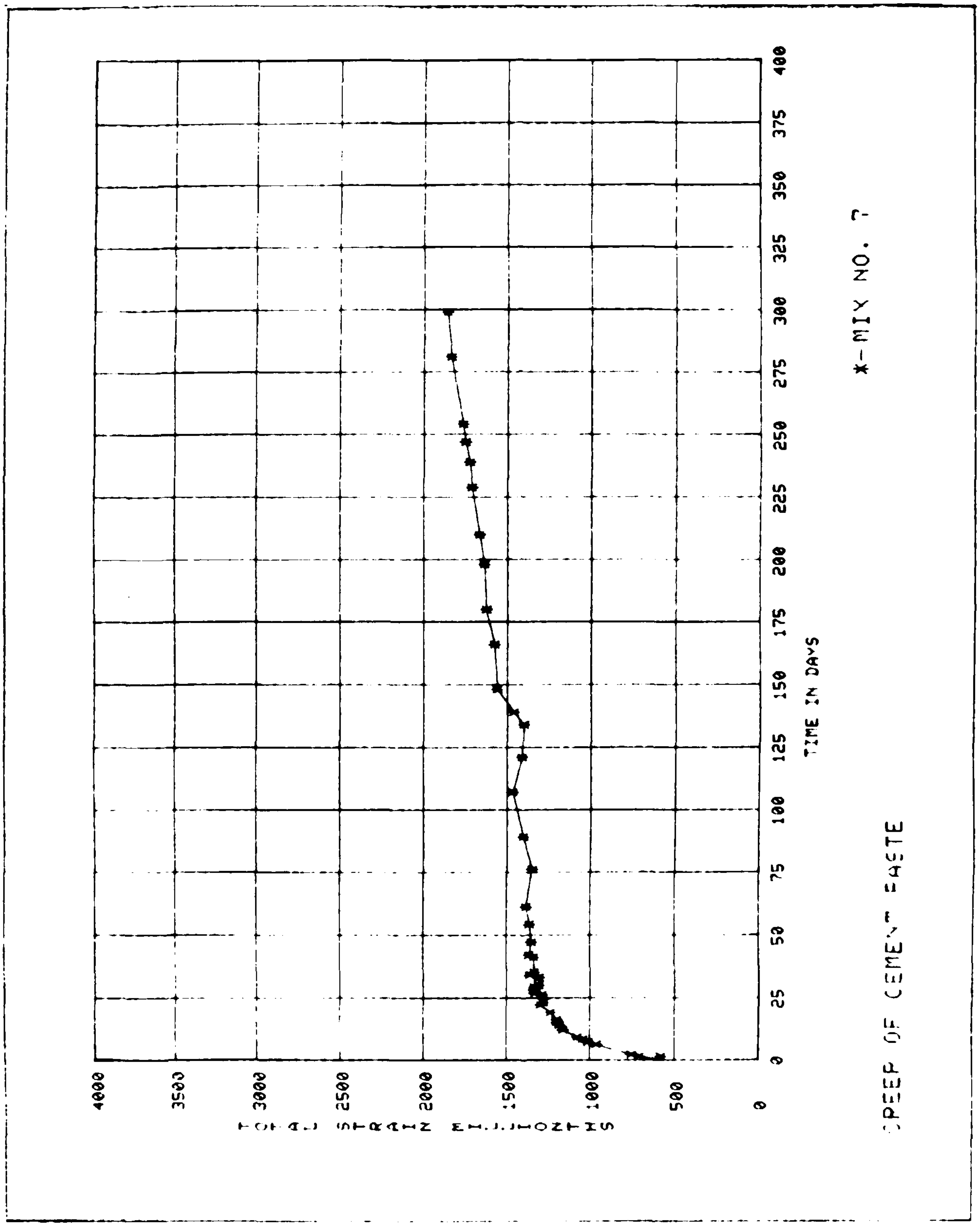

CREEP OF CEMENT PASTE
*—MIX NO. 5
TOTAL STRAIN MILLIONTHS
0
500
1000
1500
2000
2500
3000
3500
4000
TIME(DAYS)
0
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400

PLATE A22



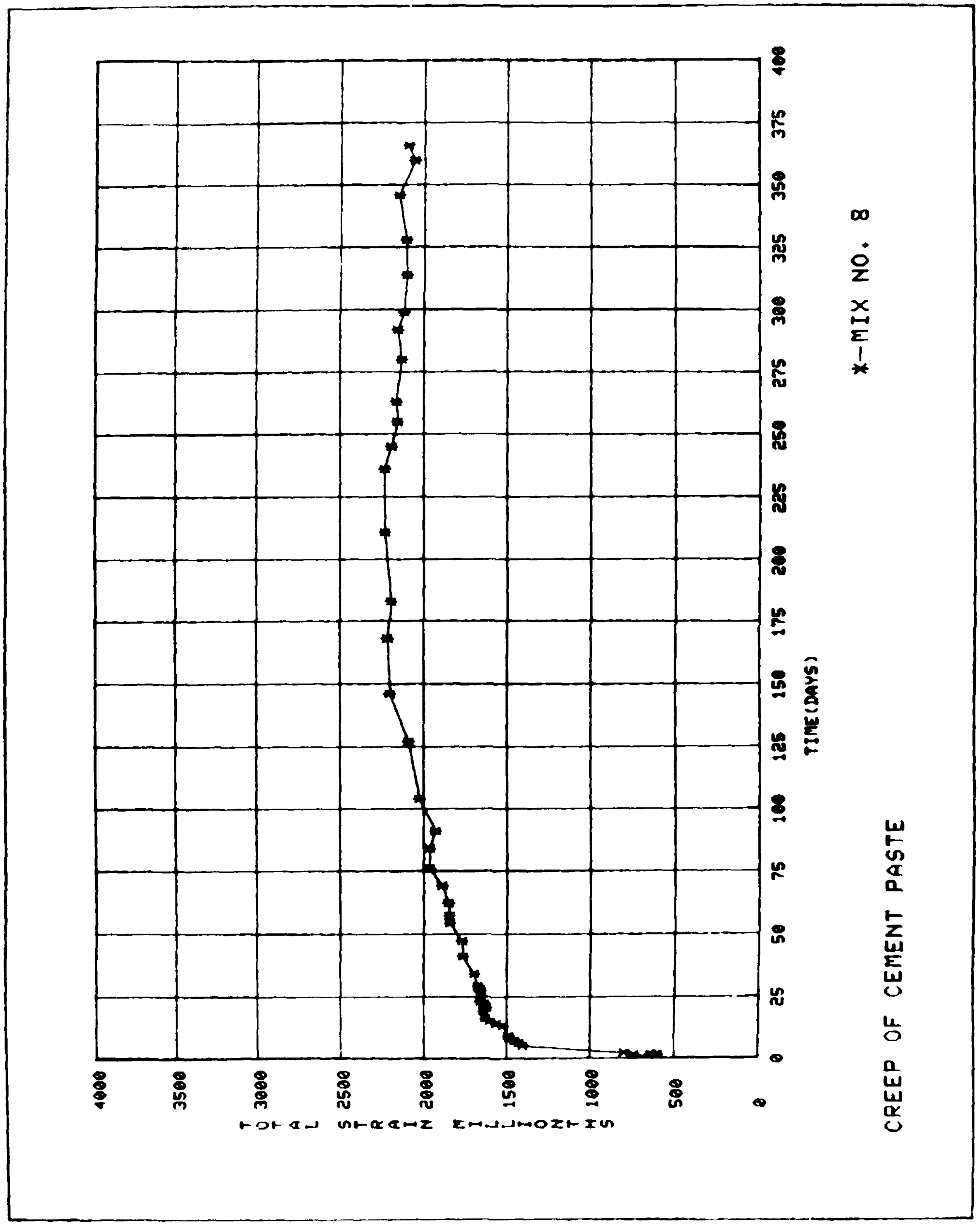
X-MIX NO. 6

CREEP OF CEMENT PASTE



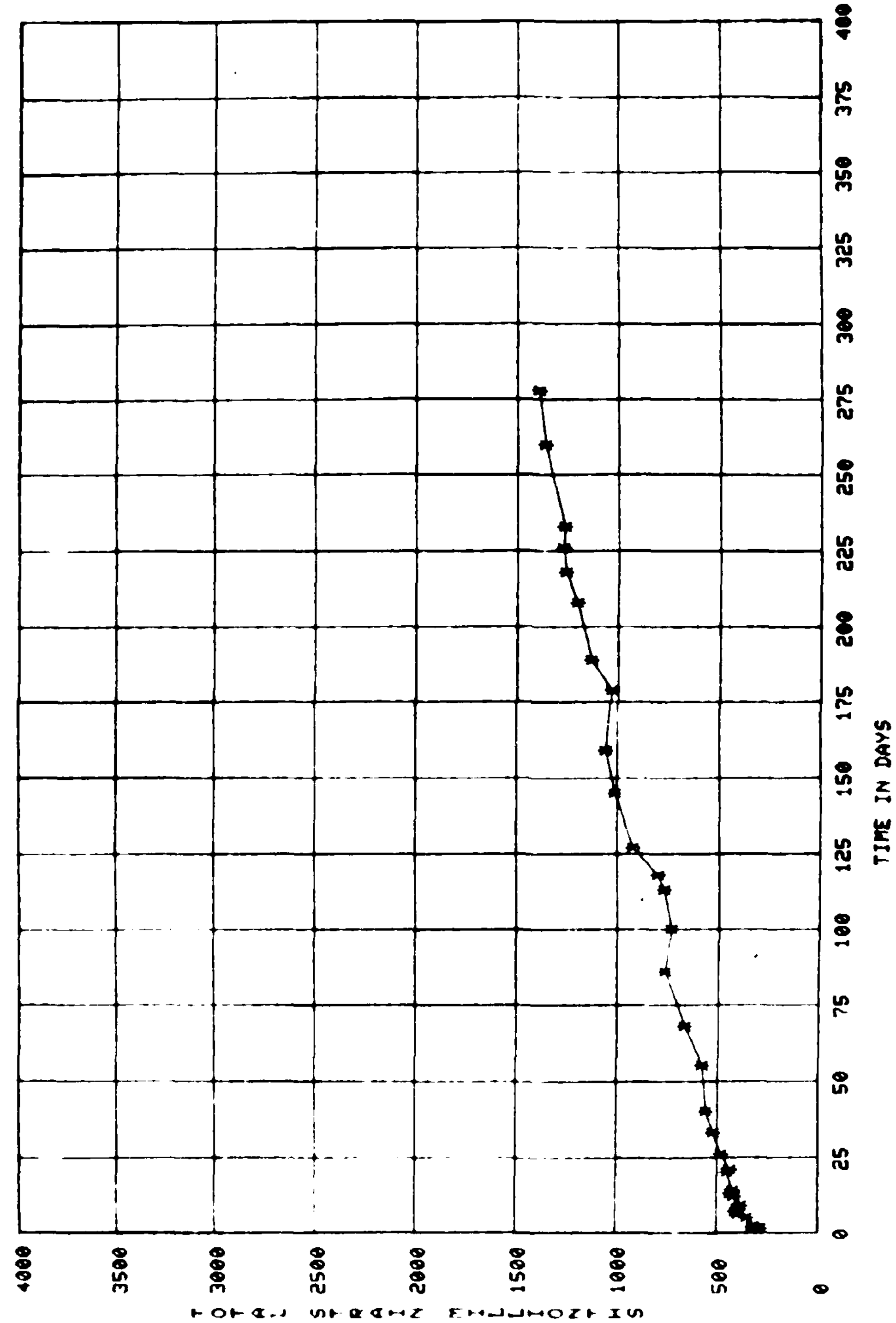
*-MIX NO. 7
TIME IN DAYS
0
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
4000
3500
3000
2500
2000
1500
1000
500
0

PLATE A24



CREEP OF CEMENT PASTE
*—MIX NO. 8
TIME(DAYS)
TOTAL STRAIN MILLIONTHS
0
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
500
1000
1500
2000
2500
3000
3500
4000

PLATE A25



*—MIX NO. 9

CREEP OF CEMENT PASTE

PLATE A26

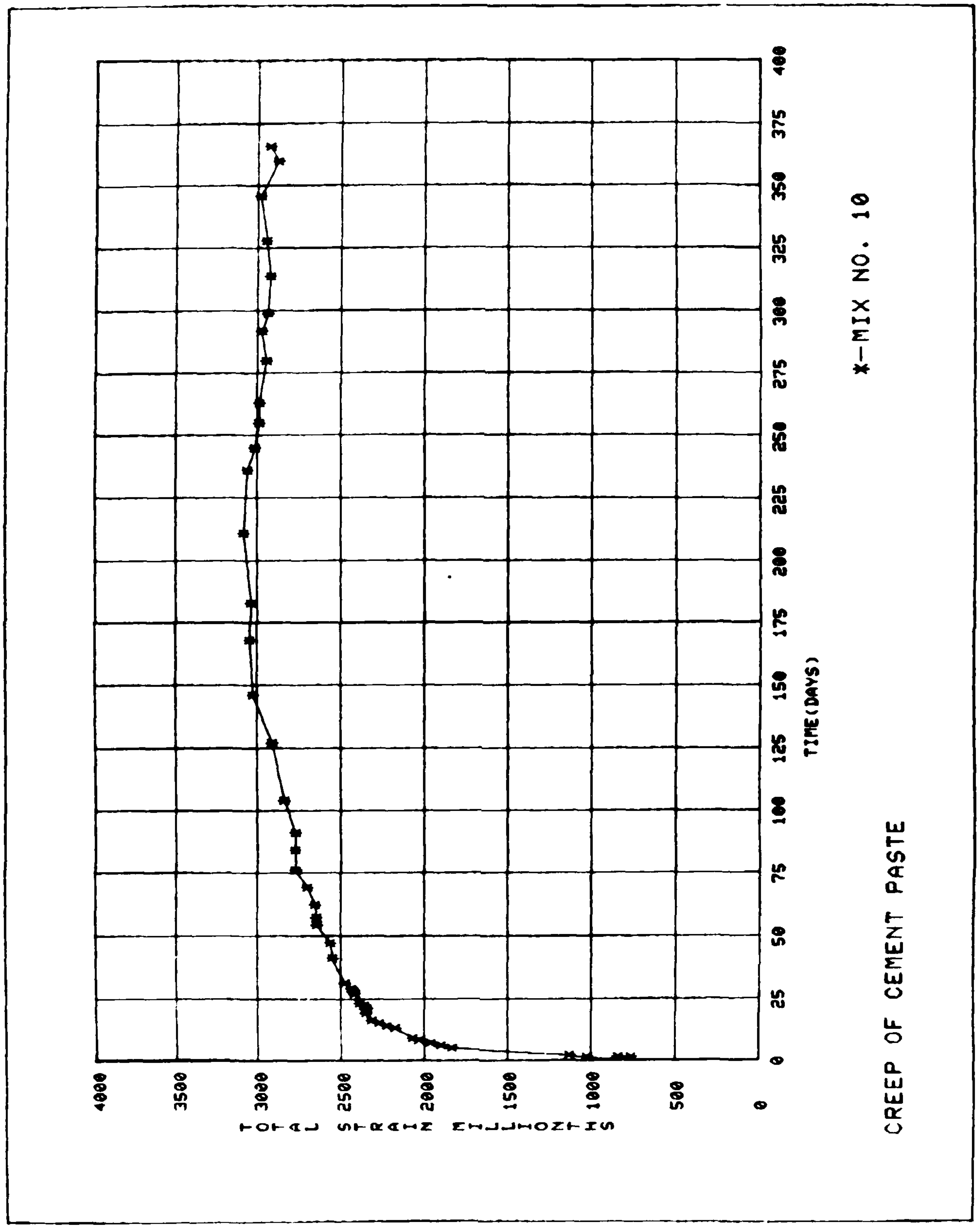
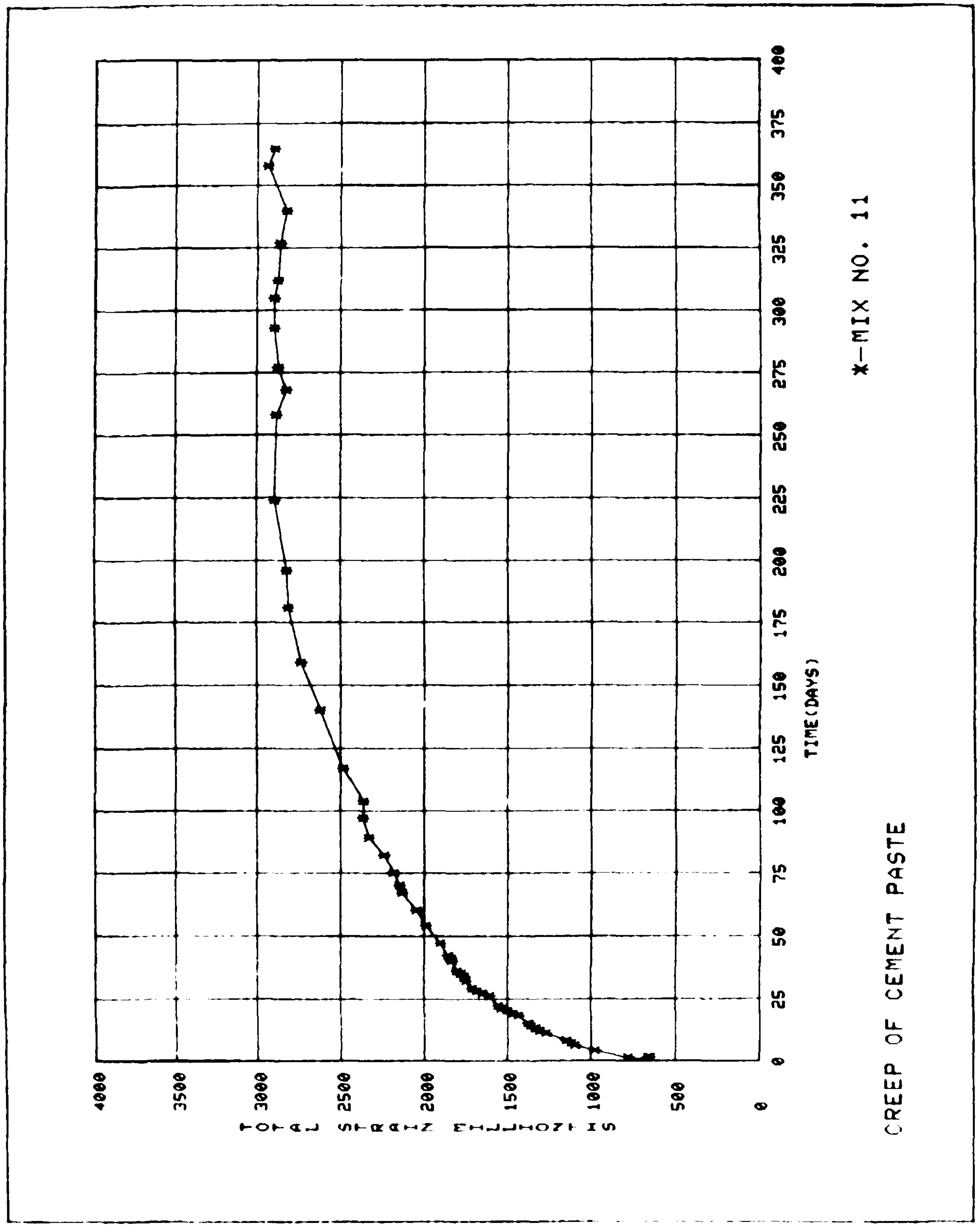
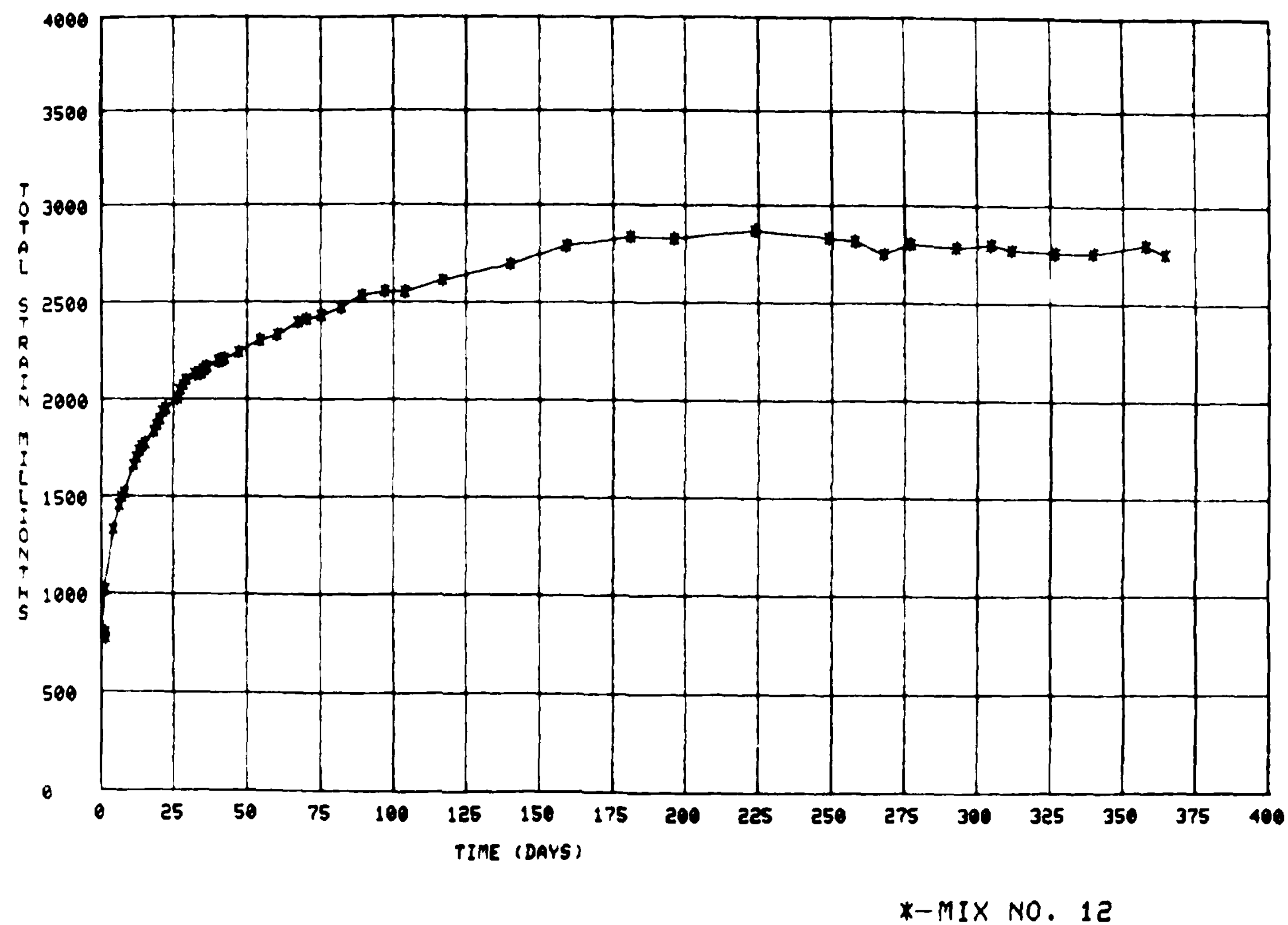

CREEP OF CEMENT PASTE
*-MIX NO. 10
TIME(DAYS)
TOTAL STRAIN MILLIONTHS
0
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
0
500
1000
1500
2000
2500
3000
3500
4000

PLATE A27

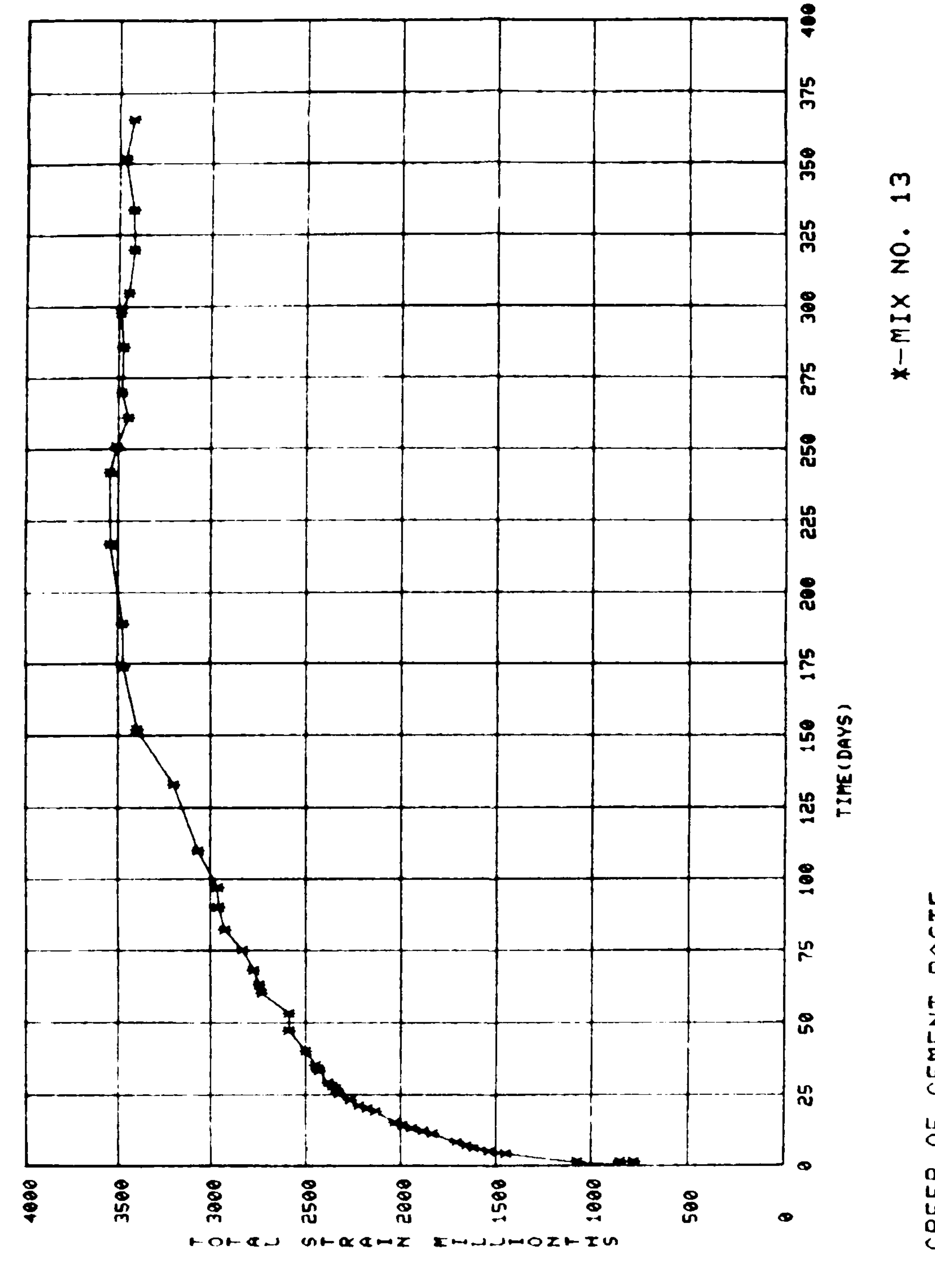


TIME(DAYS)
0
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
0
500
1000
1500
2000
2500
3000
3500
4000
*-MIX NO. 11
CREEP OF CEMENT PASTE

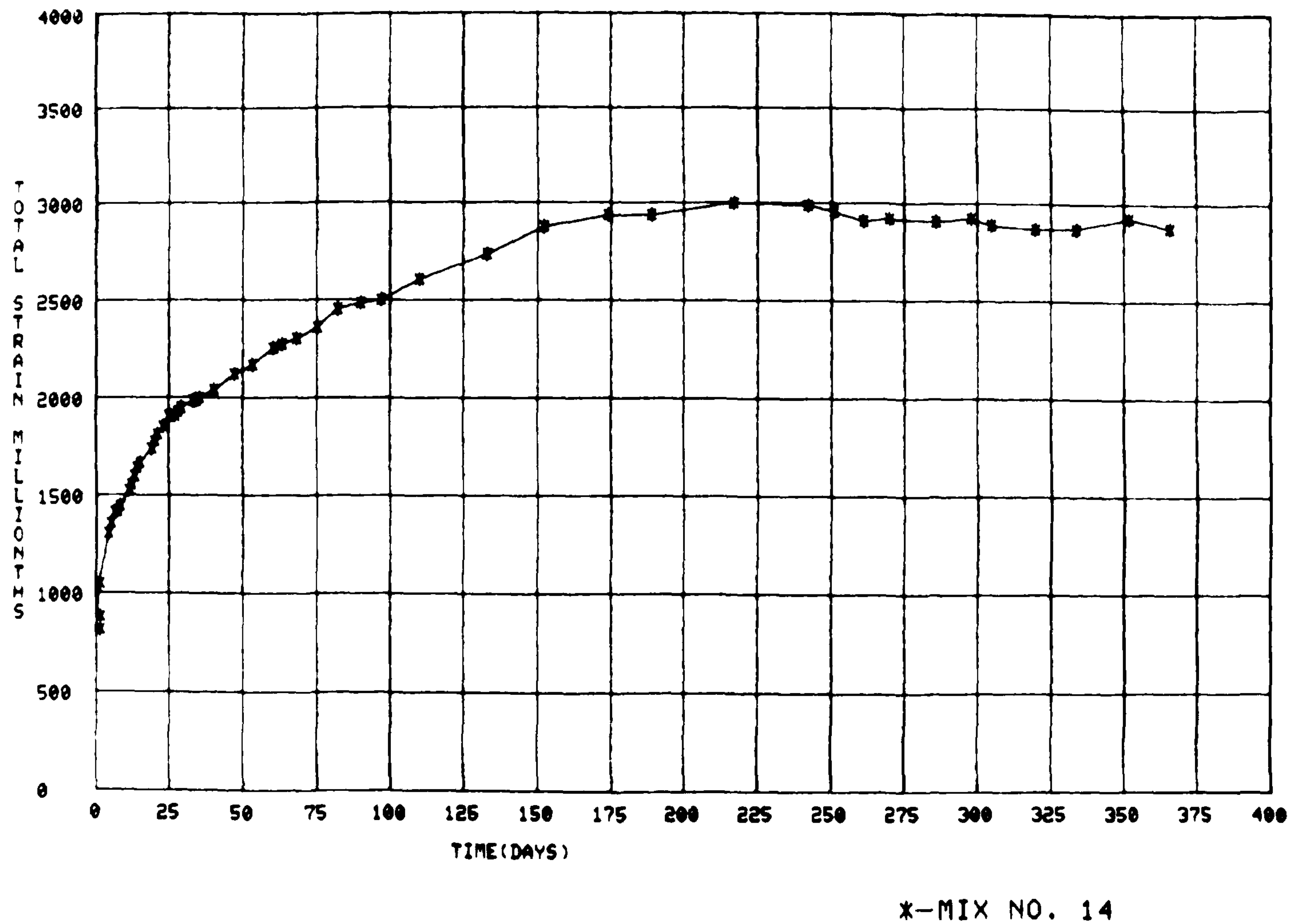
PLATE A28



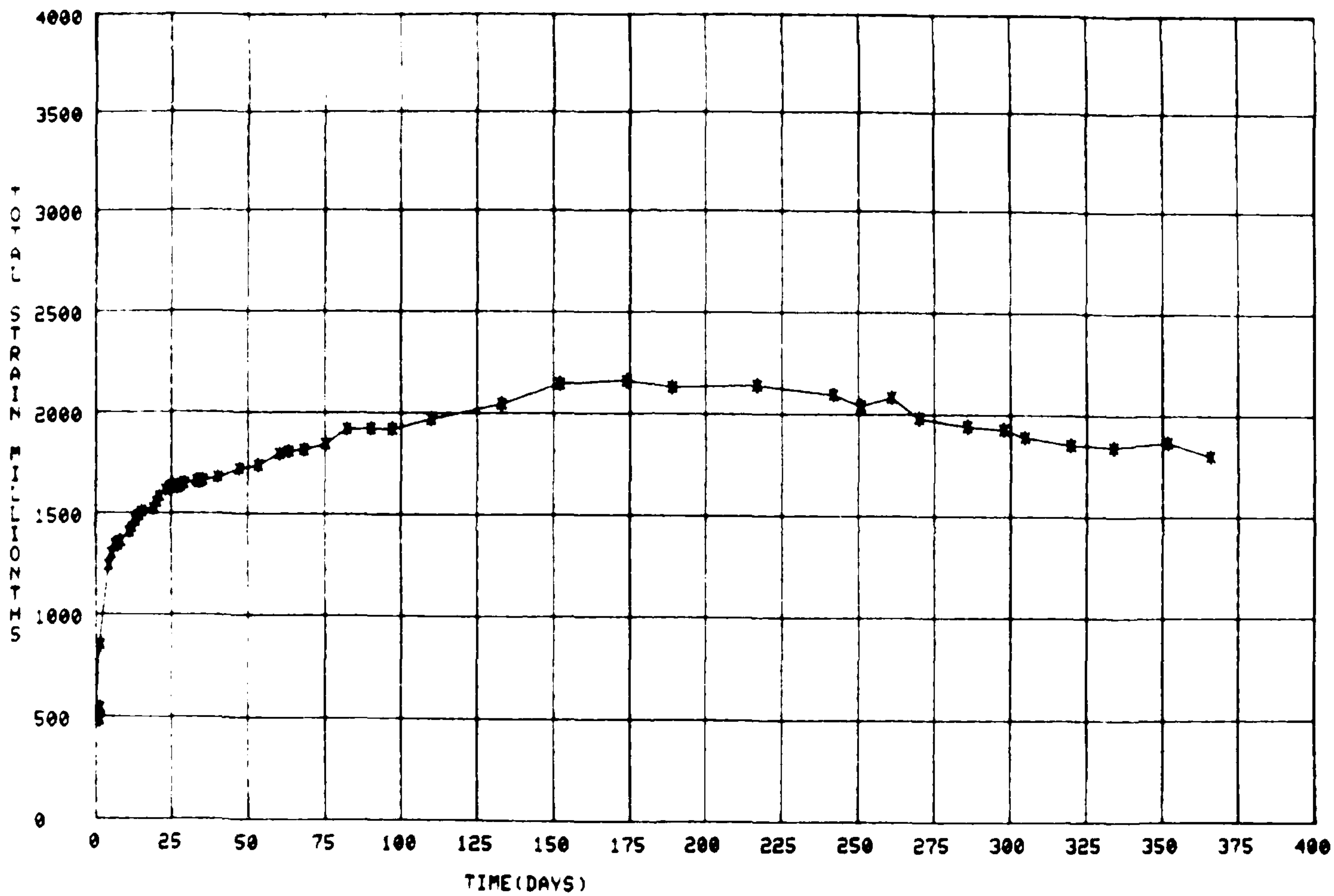
CREEP OF CEMENT PASTE



CREEP OF CEMENT PASTE



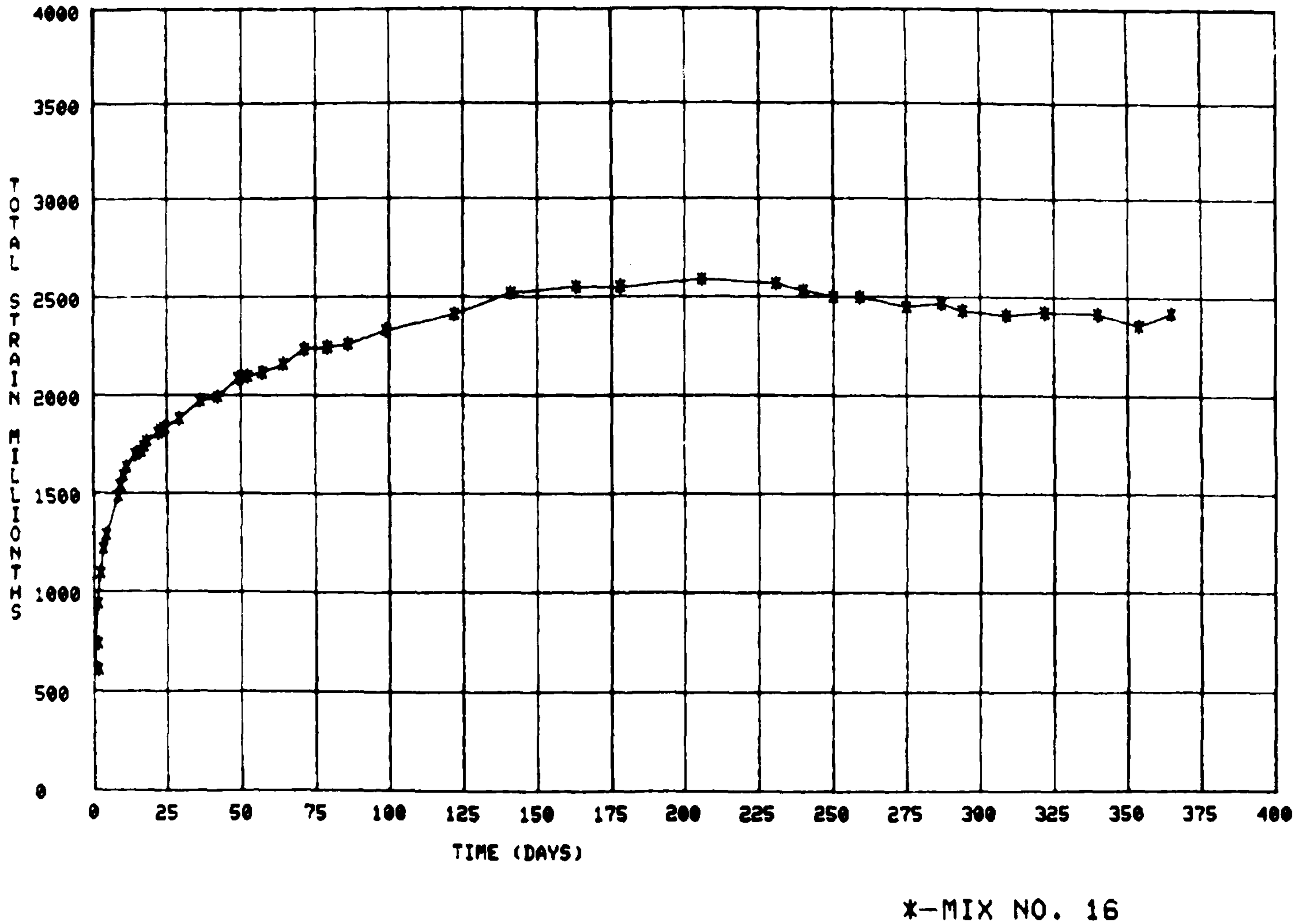
CREEP OF CEMENT PASTE



*-MIX NO. 15

CREEP OF CEMENT PASTE

PLATE A32



CREEP OF CEMENT PASTE

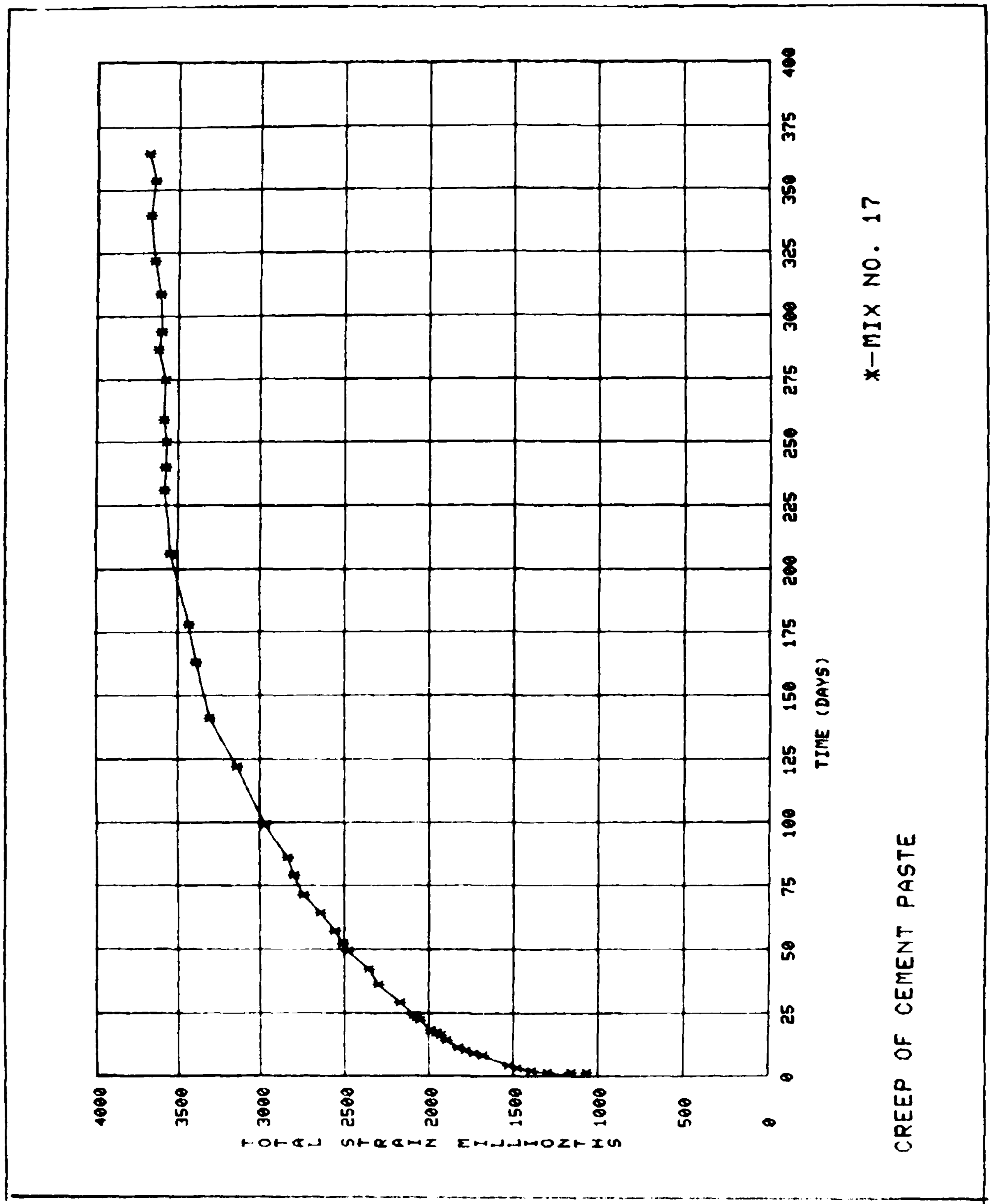

CREEP OF CEMENT PASTE
X-MIX NO. 17
TIME (DAYS)
0
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
0
500
1000
1500
2000
2500
3000
3500
4000

PLATE A34

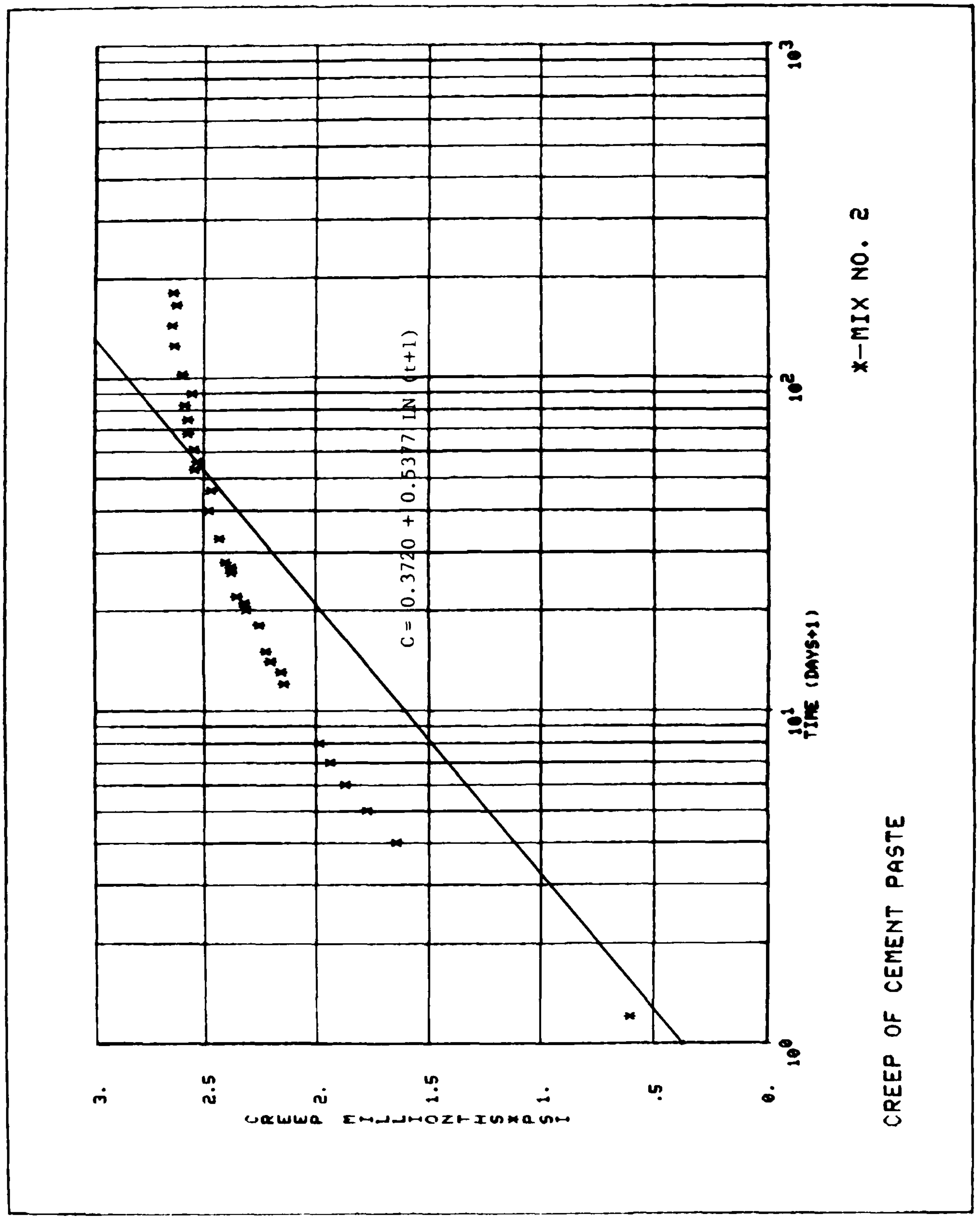

CREEP OF CEMENT PASTE
X-MIX NO. 2
C = 0.3720 + 0.5377 LN (t+1)
TIME (DAYS+1)
10⁰
10¹
10²
10³
0.
.5
1.
1.5
2.
2.5
3.

PLATE A35

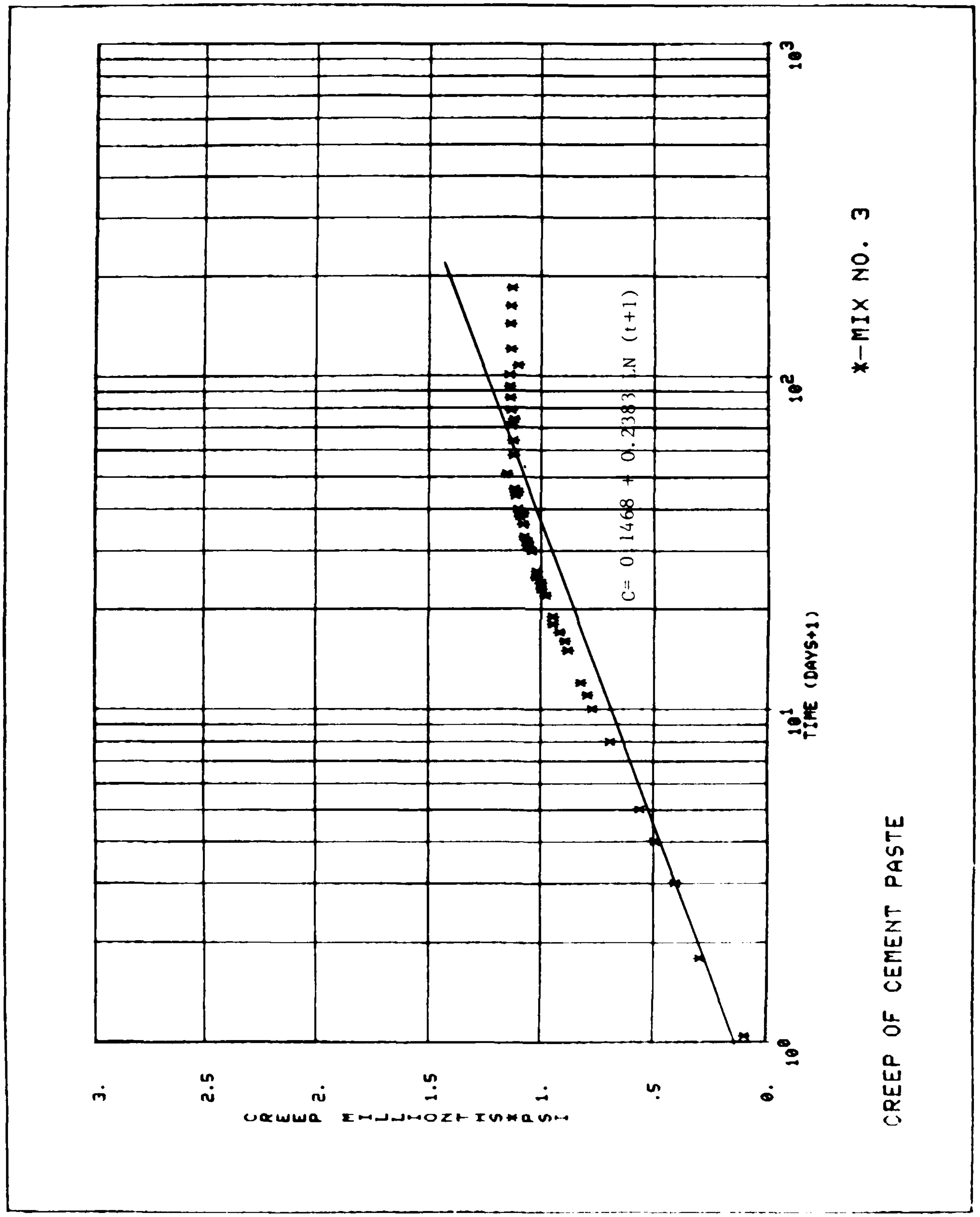
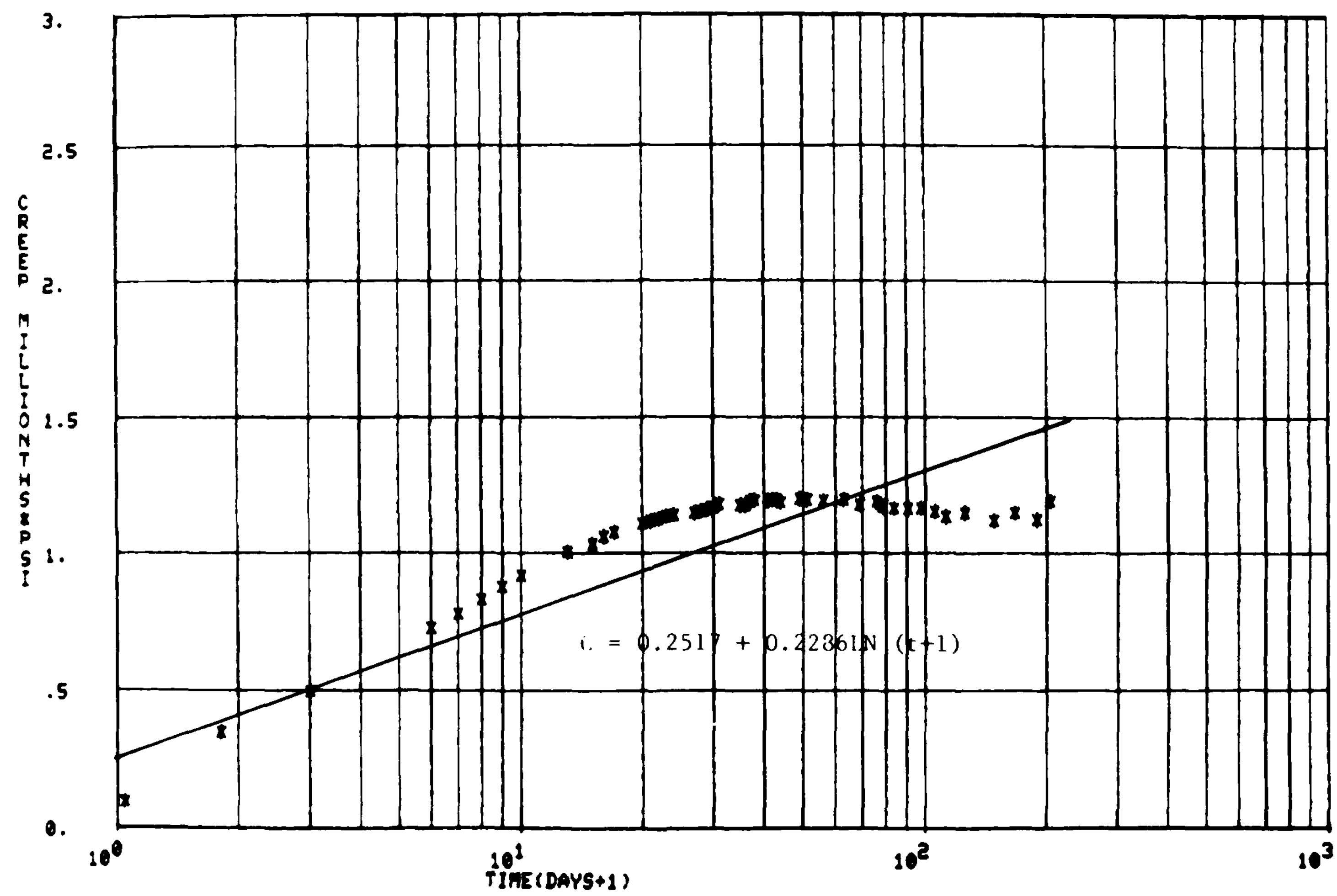
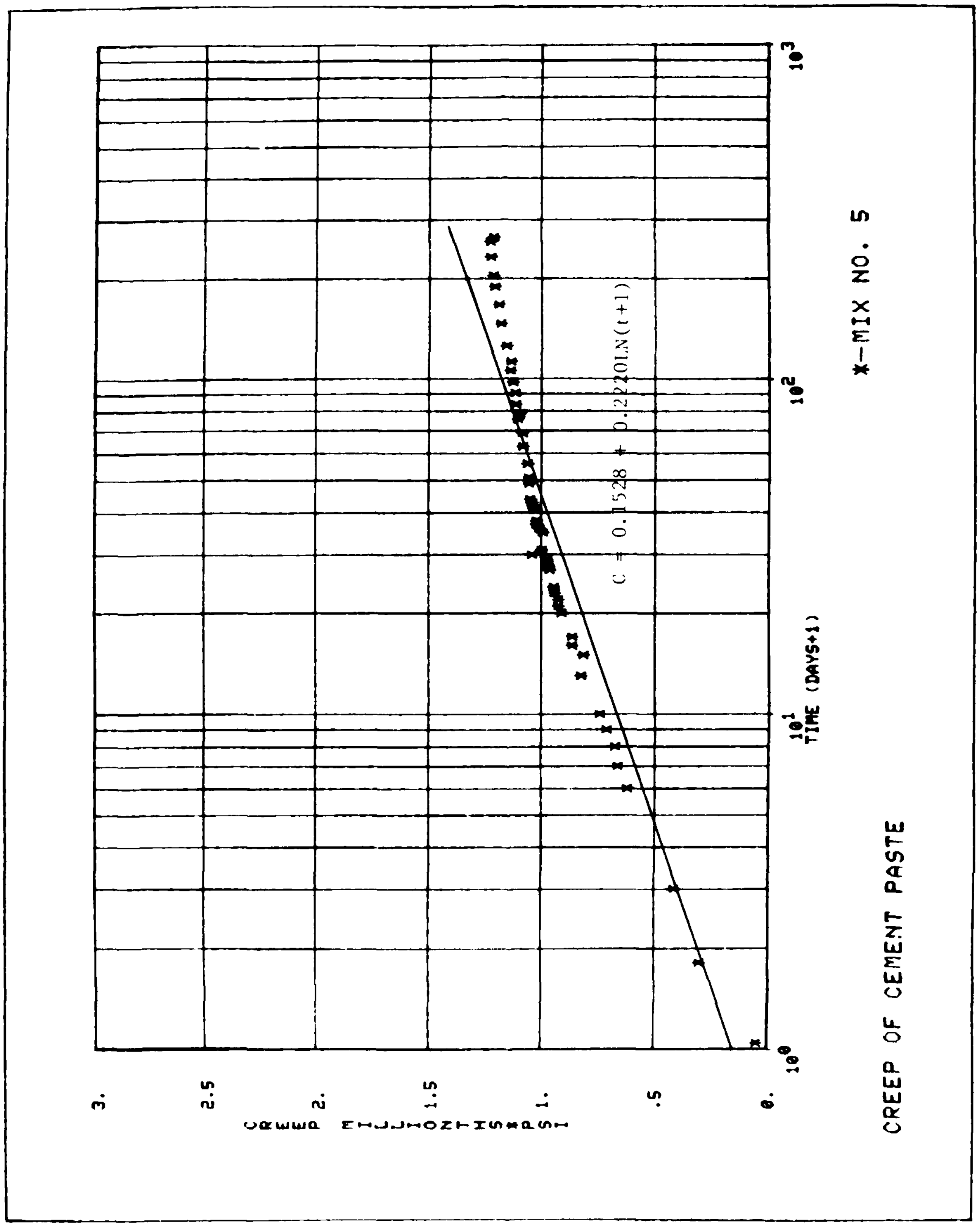
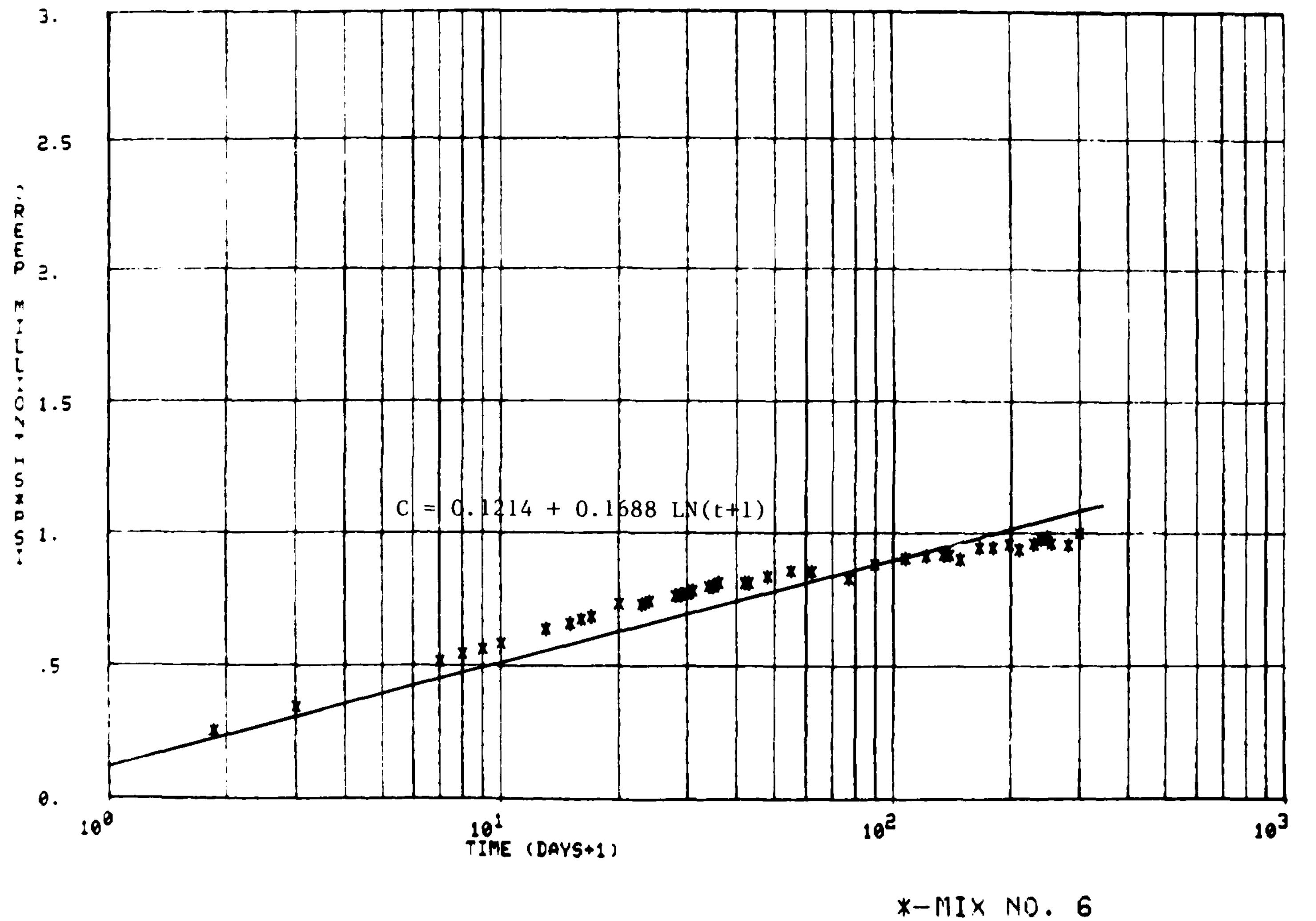

CREEP OF CEMENT PASTE
*—MIX NO. 3
C= 0.1468 + 0.2383 LN (t+1)
CREEP MILLIONTHS/PSI
TIME (DAYS+1)
3.
2.5
2.
1.5
1.
.5
0.
10^0
10^1
10^2
10^3

PLATE A36



CREEP OF CEMENT PASTE


CREEP OF CEMENT PASTE
*-MIX NO. 5
C = 0.1528 + 0.2220LN(t+1)
TIME (DAYS+1)
10^0
10^1
10^2
10^3
0.
.5
1.
1.5
2.
2.5
3.



CREEP OF CEMENT PASTE

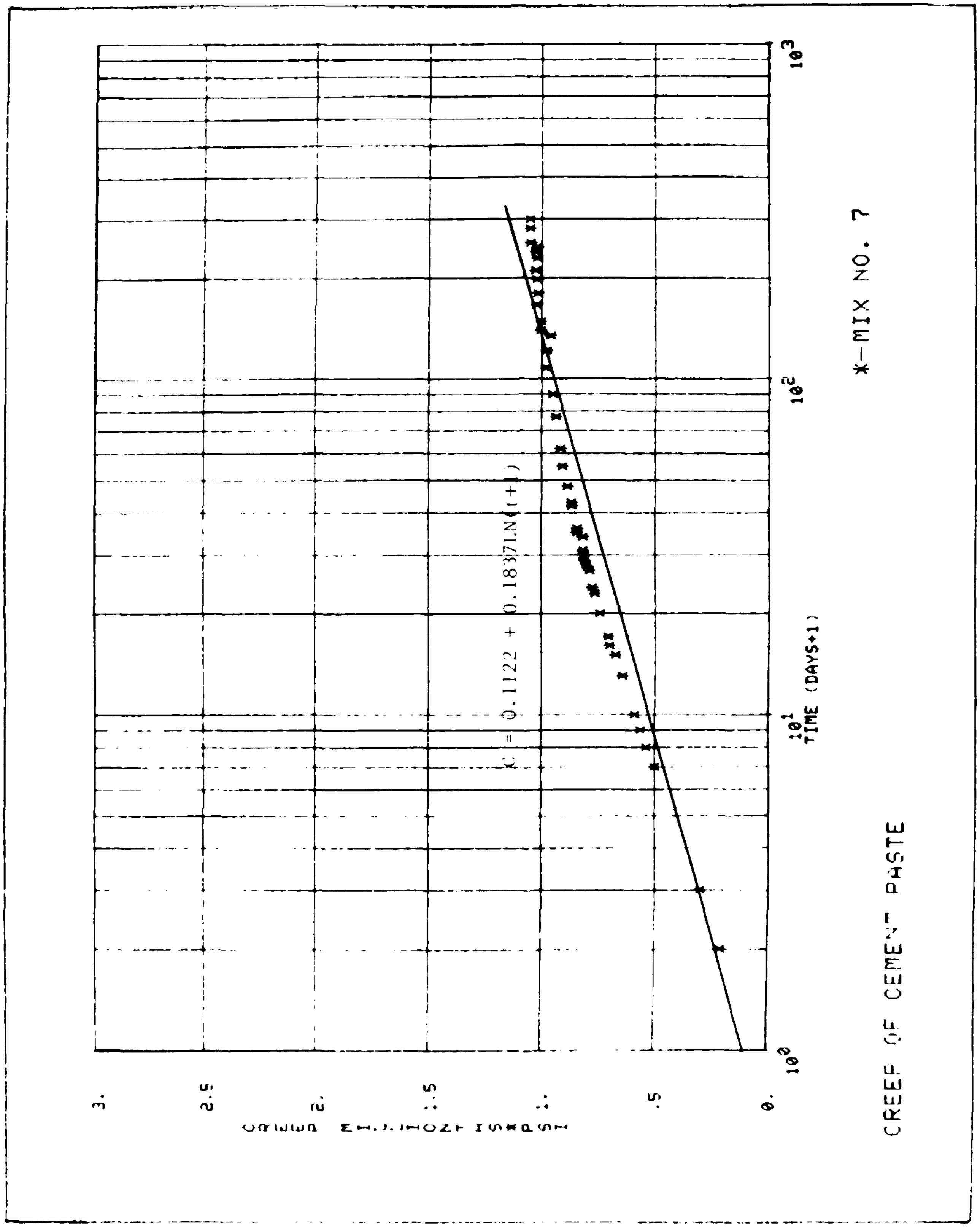
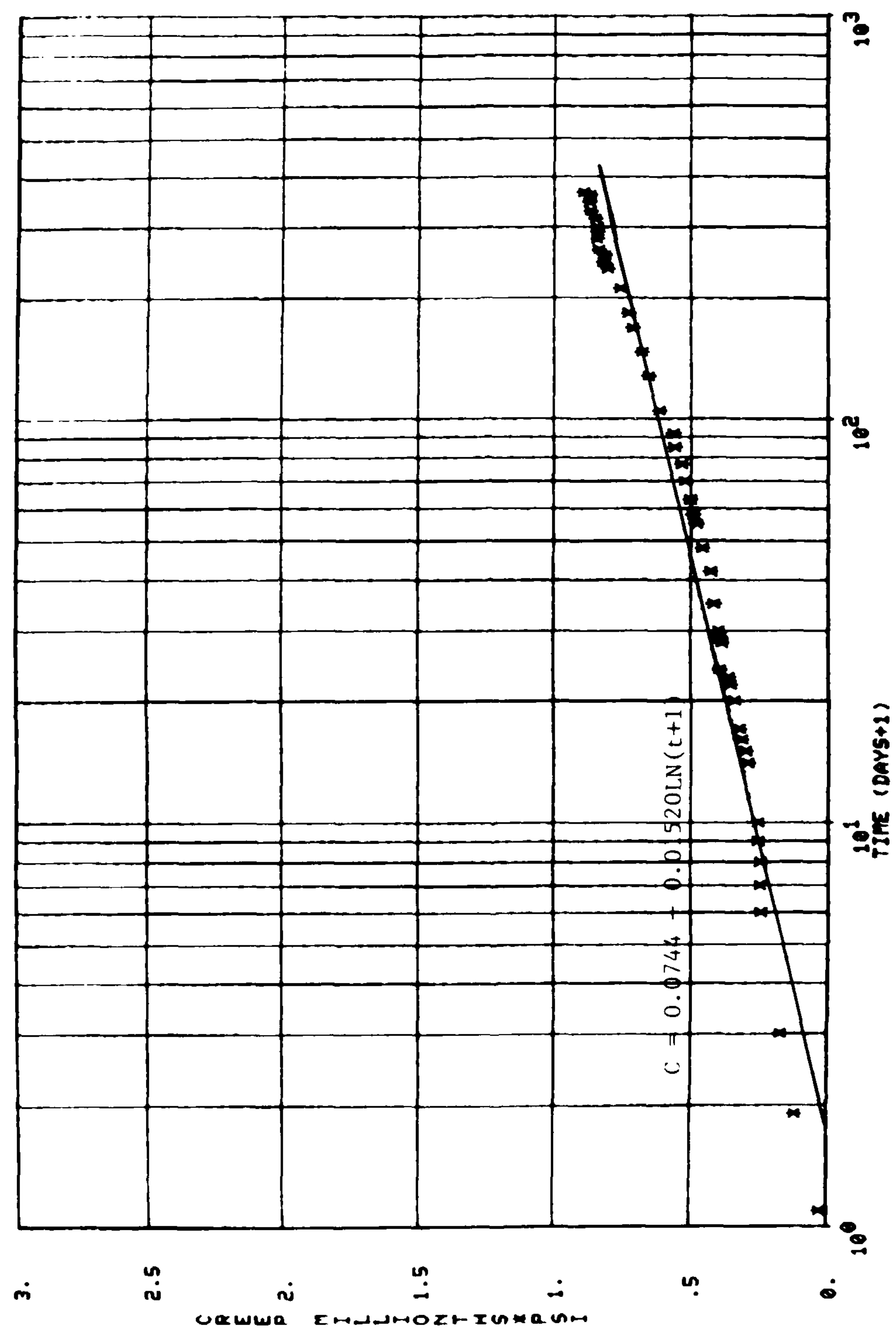

CREEP OF CEMENT PASTE
*-MIX NO. 7
C = 0.1122 + 0.1837LN(t+1)
TIME (DAYS+1)
10^0
10^1
10^2
10^3
0.
.5
1.
1.5
2.
2.5
3.

PLATE A40



CREEP OF CEMENT PASTE

X-MIX NO. 8

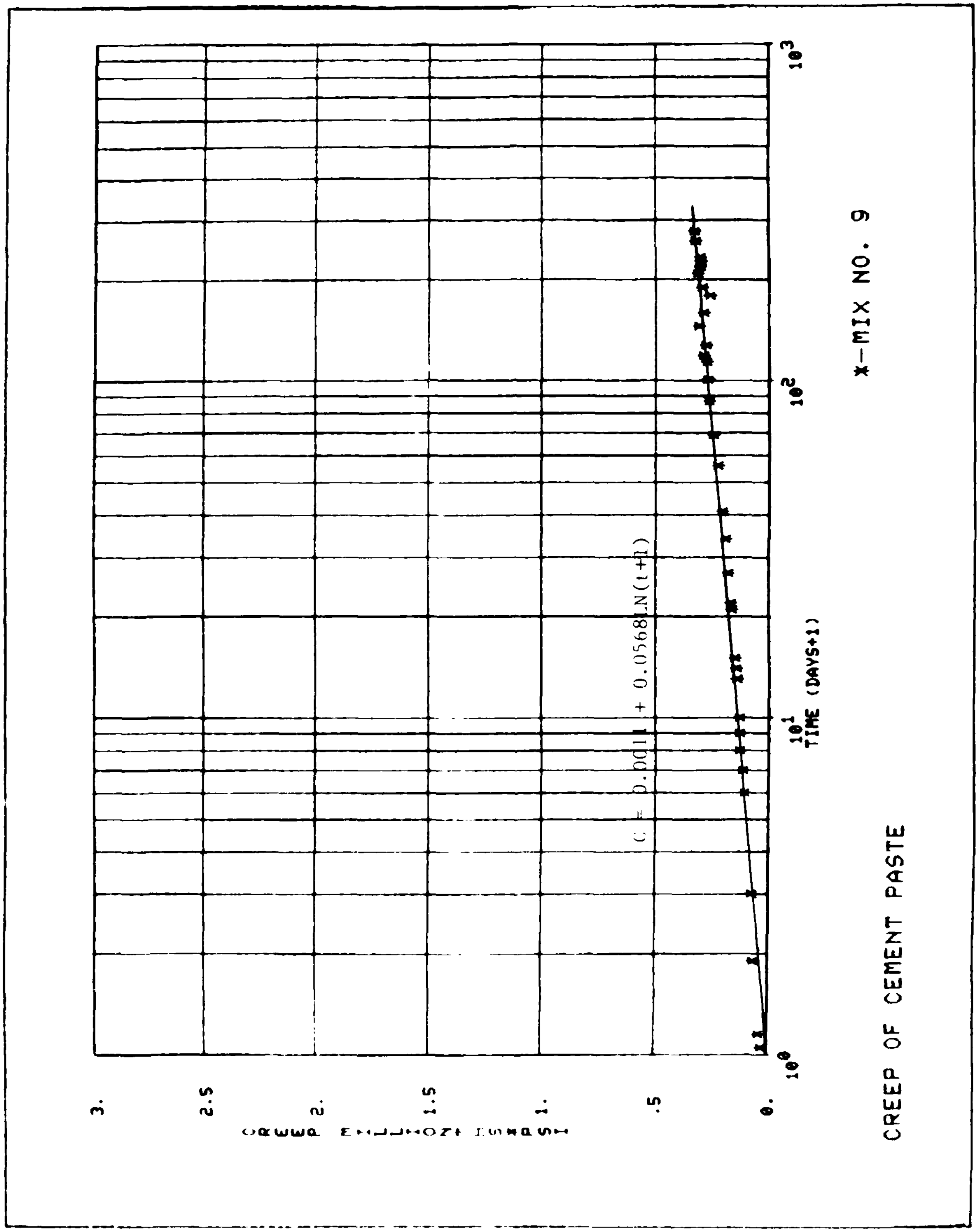
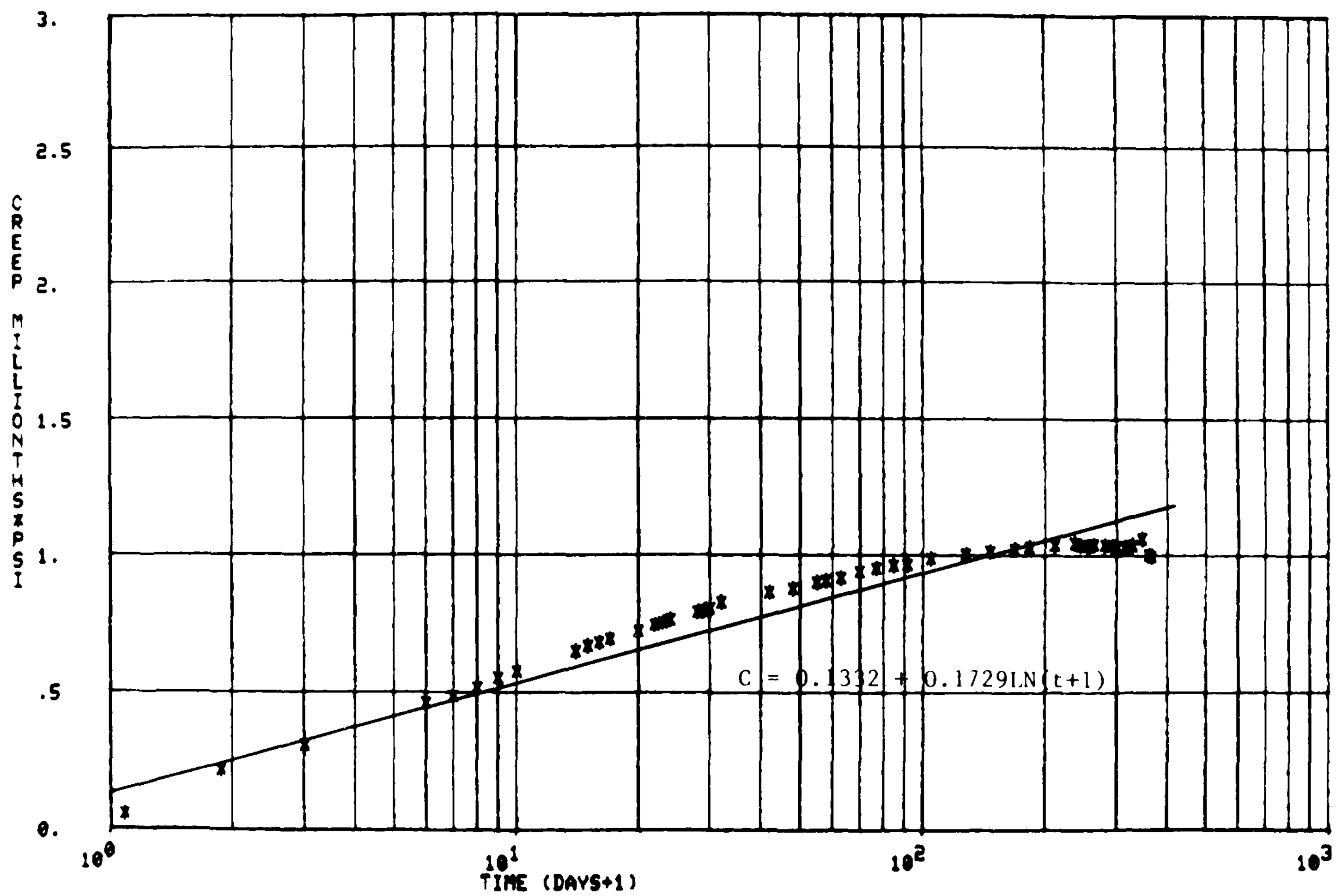
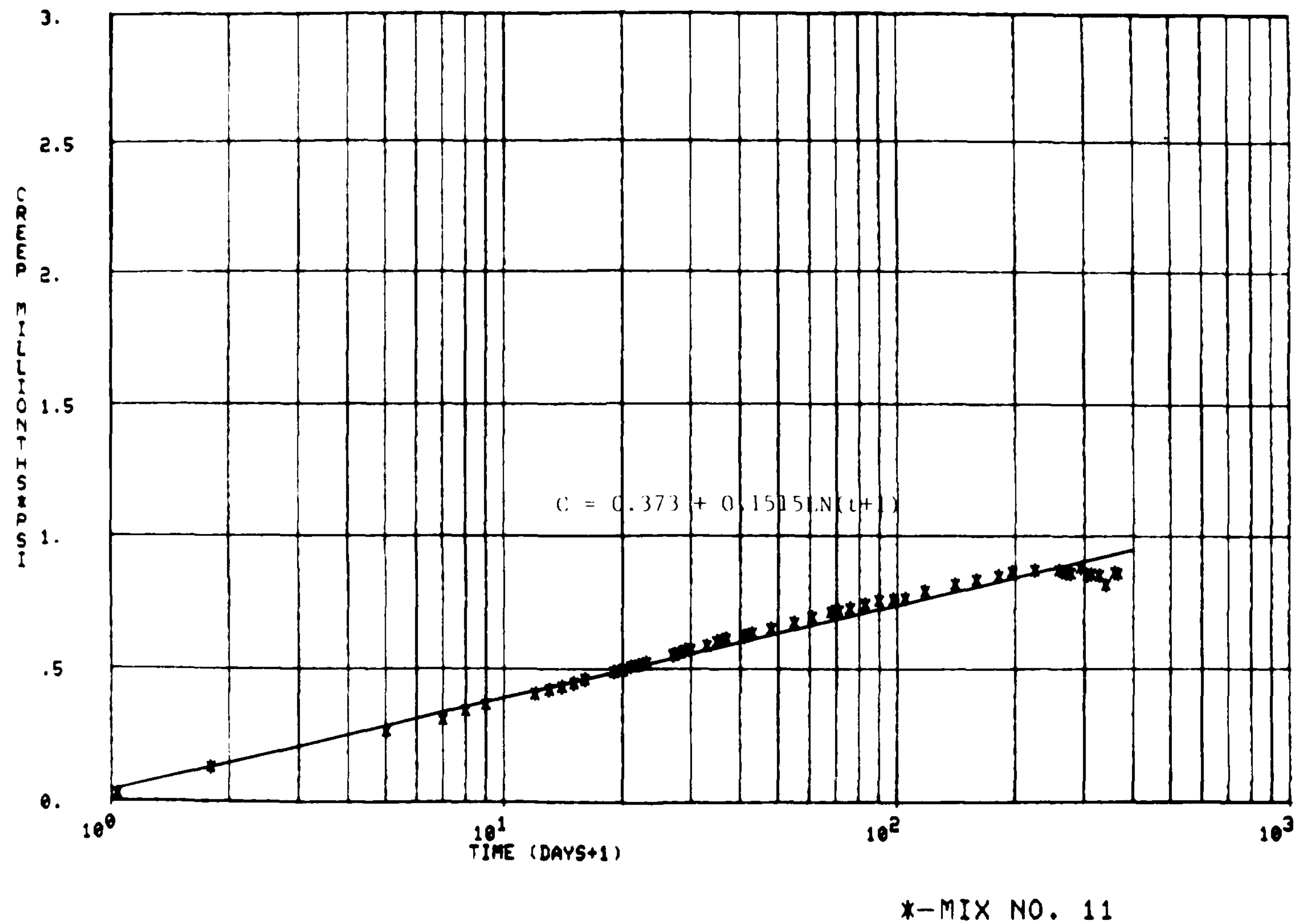

CREEP OF CEMENT PASTE
X-MIX NO. 9
C = 0.0011 + 0.0568LN(t+1)
TIME (DAYS+1)
10^0
10^1
10^2
10^3
0.
.5
1.
1.5
2.
2.5
3.

PLATE A52

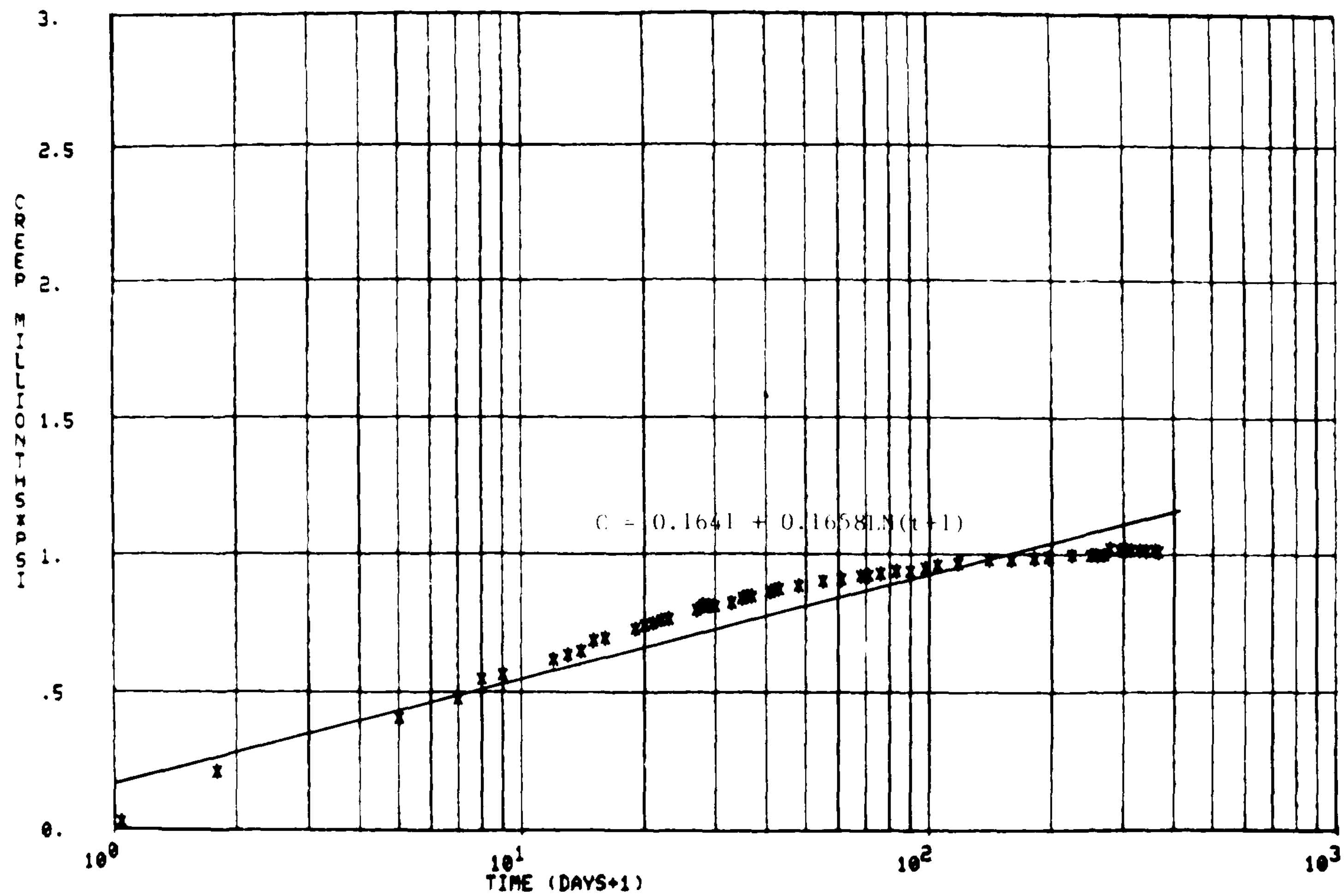


CREEP OF CEMENT PASTE



CREEP OF CEMENT PASTE

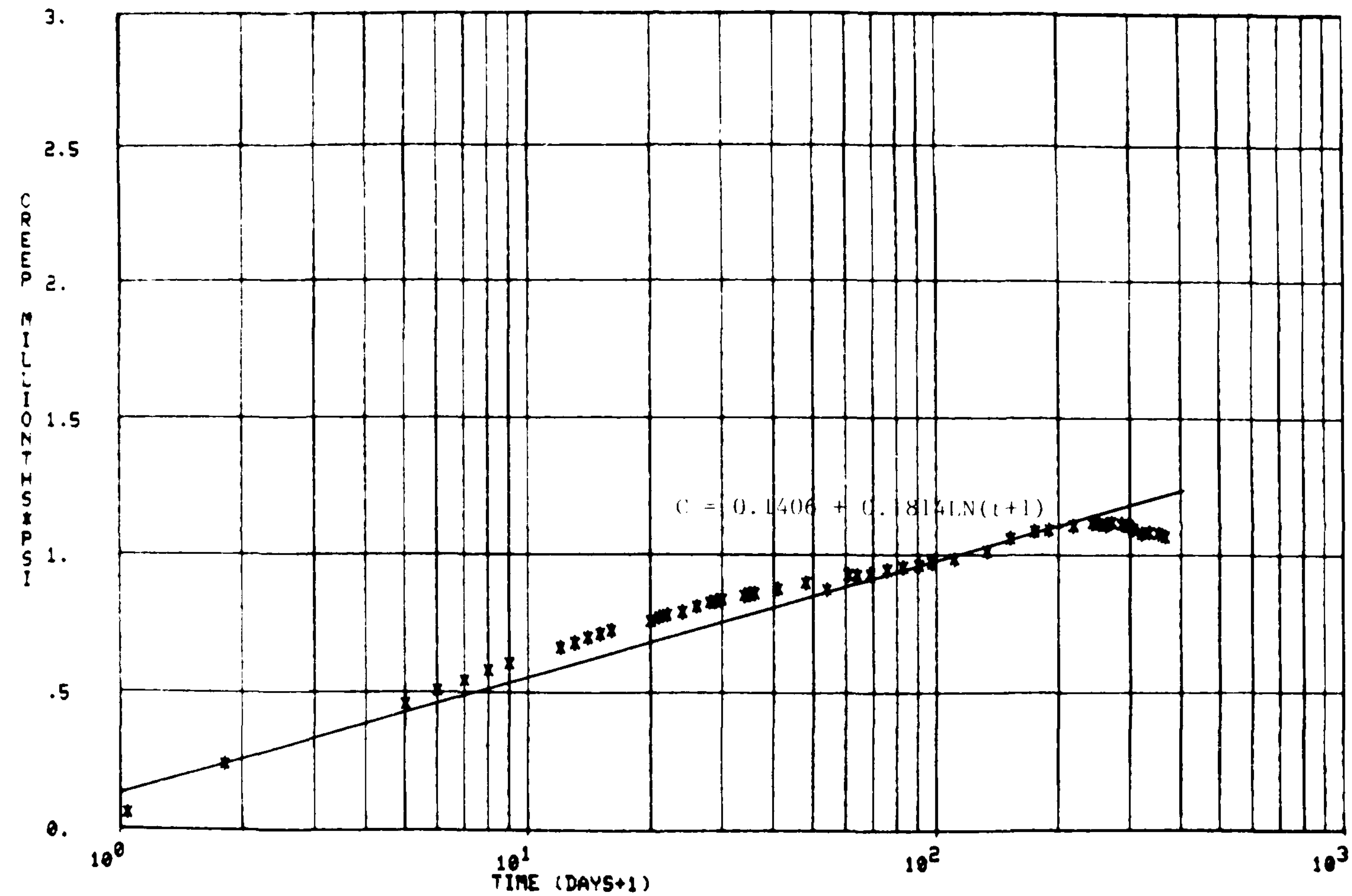
PLATE A44



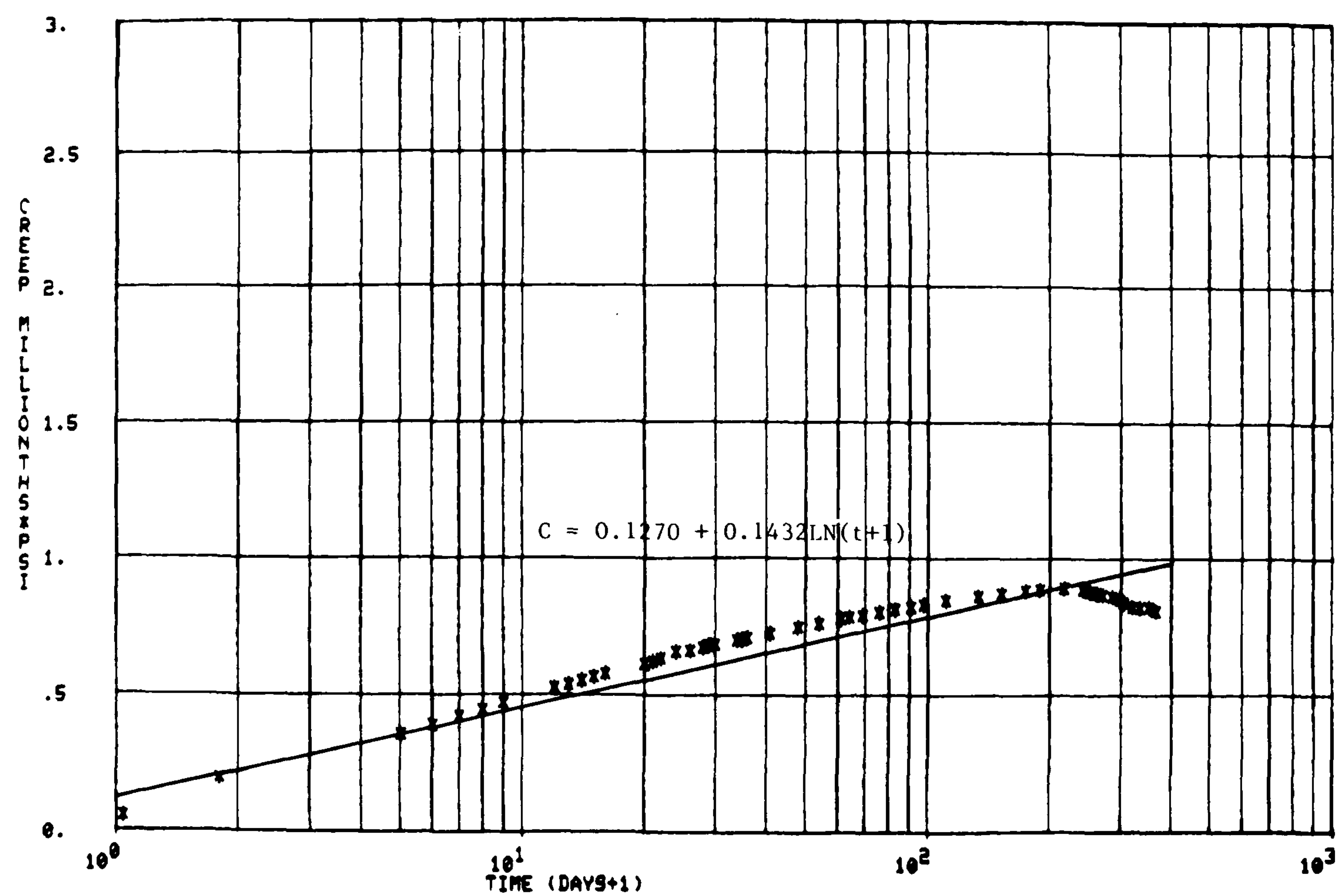
*–MIX NO. 12

CREEP OF CEMENT PASTE

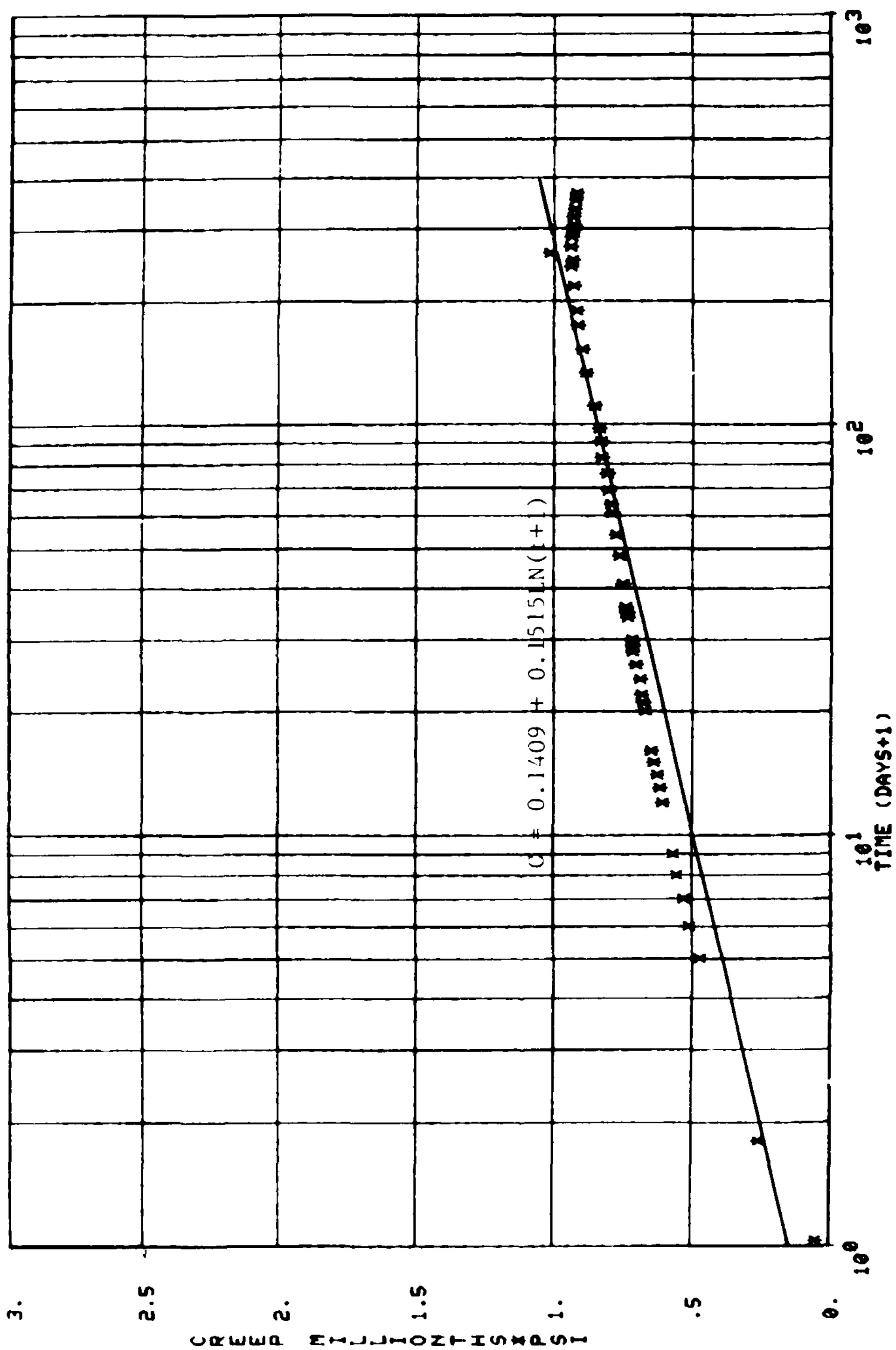
PLATE A45



CREEP OF CEMENT PASTE



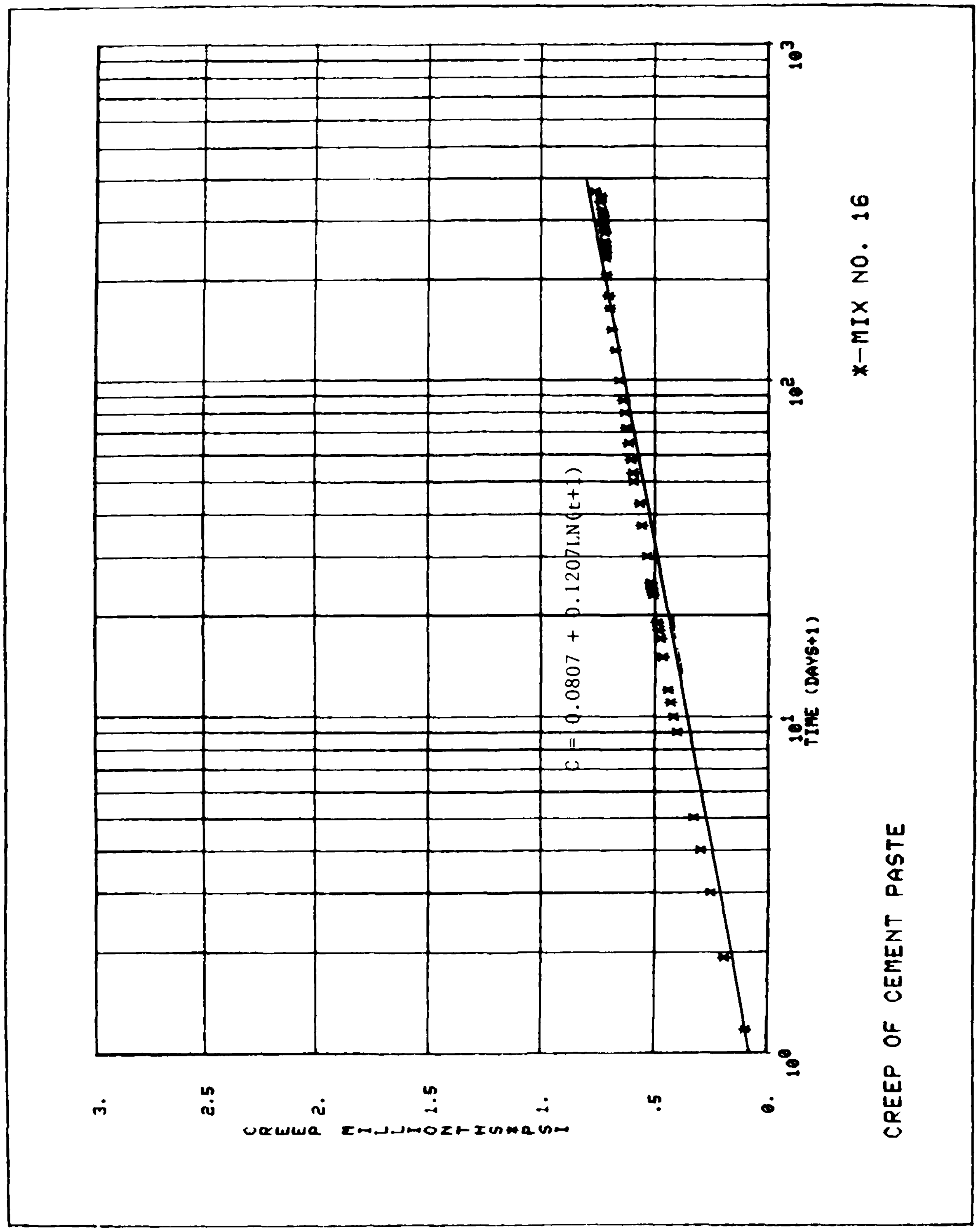
CREEP OF CEMENT PASTE



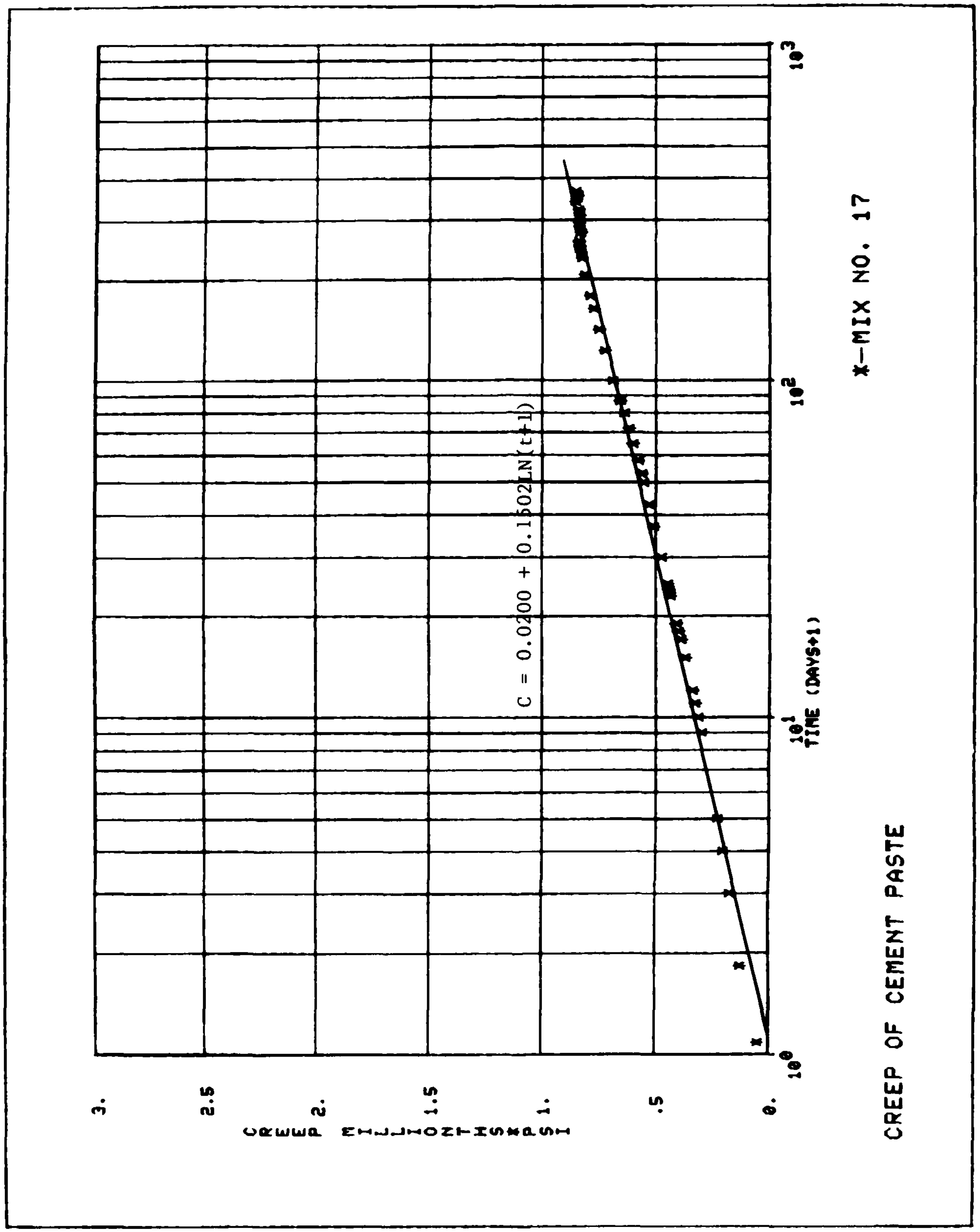
*—MIX NO. 15

CREEP OF CEMENT PASTE

PLATE A48



CREEP OF CEMENT PASTE
X-MIX NO. 16
C = 0.0807 + 0.1207LN(t+1)
TIME (DAYS+1)
CREEP MILLIONTHS/PSI
0.
.5
1.
1.5
2.
2.5
3.
10^0
10^1
10^2
10^3



CREEP OF CEMENT PASTE
*—MIX NO. 17
C = 0.0200 + 0.1502LN(t+1)
TIME (DAYS+1)
10^0
10^1
10^2
10^3
0.
.5
1.
1.5
2.
2.5
3.

APPENDIX B: PETROGRAPHIC EXAMINATION--CEMENTS

Background

1. A total of 56 cements and blended cements from 27 different sources were examined by X-ray diffraction to determine the crystalline phases that were detectable. Selective chemical dissolution treatments were used as needed to aid in the identification procedure.

Samples

2. The samples are identified alphabetically by sources:

Structures Laboratory (SL) Serial No. RC-	Cement Type	Source
705	Portland II	Alabama, Source 1
714	Portland I	Alabama, Source 2
751	Portland I	Alabama, Source 3
752	Blend IS (Slag)	Alabama, Source 3
731	Portland I	Arizona, Source 1
732	Blend IP	Arizona, Source 1
763	Portland II (Dry Kiln)	Arizona, Source 2
764	Portland II (Preheater)	Arizona, Source 2
715	Portland I	Colorado
753	Portland II (Preheater)	Colorado
754	Portland II (Preheater)	Colorado
832	Portland V	Colorado
USAECE-1C-1*	Blend (Slag)	Germany, Source 1
USAECE-1C-2*	Blend (Slag)	Germany, Source 2
733	Portland I (Preheater)	Georgia
765	Portland I	Iceland
766	Portland I	Iceland
725	Portland I	Illinois
726(2)	Blend IP	Illinois
772	Portland II (Preheater)	Kansas
755	Portland V	Manitoba, Canada
756(2)	Portland I	Maryland
761	Portland I	Maryland
758	Blend IS (slag)	Michigan, Source 1
719	Blend IP	Michigan, Source 2
720	Portland I	Michigan, Source 2

*Not an RC serial No.

Structures Laboratory (SL) Serial No. RC--	Cement Type	Source
734	Portland I	Michigan, Source 2
735	Blend IP	Michigan, Source 2
829	Portland I	Michigan, Source 2
830	Blend IP	Michigan, Source 2
688 (2)(3)	Portland I	Mississippi
721	Blend IP	Missouri
722	Portland I	Missouri
738	Portland I	Missouri
739	Blend IP	Missouri
740	Blend IP (made with bottom ash)	Missouri
831	Portland II	New York
746	Portland I (Preheater)	Ohio
769	Blend IS (Slag)	Penn., Source 1
770	Portland I	Penn., Source 1
833	Blend IS (Slag)	Penn., Source 1
834	Portland I	Penn., Source 2
716	Portland I	South Carolina
717	Blend IP	South Carolina
729	Portland I	South Carolina
730	Blend IP	South Carolina
736	Portland I, II (Preheater)	Texas, Source 1
737	Portland III	Texas, Source 1
744	Portland I	Texas, Source 2
745	Blend IP	Texas, Source 2
733	Portland I	Georgia
807*	Blend IP, MS	Texas, Source 2
807 (A)	Portland I	Texas, Source 2
741	Portland I	Tennessee
742	Blend IP	Tennessee
718	Portland I, II	Washington

*Made with fly ash AD-577.

Test Procedure

3. A portion of each cement was tightly packed into a sample holder and examined by X-ray diffraction in a nitrogen atmosphere to prevent hydration of the sample.

4. In all cases a sample of cement was treated with maleic acid to selectively dissolve the calcium silicates (alite, belite). The weight loss was determined and the insoluble residue was examined by X-ray diffraction. The maleic acid procedure was essentially as described by Mander, Adams, and Larkin (1974)* except that treatment time was 30 instead of 10 minutes when it was found that the shorter time did not always remove all of the calcium silicates.

* References are listed at the end of the text of this appendix.

5. Since the residue left after maleic acid treatment still contained the calcium sulfate(s) or other sulfates, Wong and Husbands (unpublished data) developed a treatment with ammonium chloride to selectively dissolve sulfate compounds. This technique was used on the maleic acid residues of some of the cements. Weight losses were determined and the insoluble residues were examined by X-ray diffraction. A description of the ammonium chloride treatment is given in Appendix B-1.

6. Immersion mounts of some of the cements or the insoluble residues were examined with a polarizing microscope. This was usually done to verify or disprove the presence of some noncement constituent that might be present.

7. The crystal form or forms of tricalcium aluminate in the cements were determined by study of X-ray diffraction patterns of insoluble residues or of as received portland or other types of cements. These were classified as cubic or noncubic (orthorhombic, monoclinic), or a mixture of cubic and noncubic forms. This was done by the presence or nonpresence of weak peaks at 4.41A,* 4.23A,* and 4.08A.* This procedure was largely based on information by Fletcher, Midgeley, and Moore (1965); by Regourd, Chromy, Hjorth, Mortureux, and Guinier (1973); by Regourd and Guinier (1974); and Kristmann (1977). A paper about the procedure for determining the form of C_3A in cement by X-ray diffraction was published by Burkes and Buck (1983).

8. The composition of the crystal phase in the solid solution calcium aluminoferrite series was determined by the position of the 141 peak that ranges between about 2.63 to 2.68 A* in X-ray diffraction patterns according to the phase that is present. This procedure was based on data by Midgley (1958); Kantro, Copeland, Weise, and Brunauer (1964); and Mather (1971); some of Mather's data were unpublished.

9. All X-ray patterns were made with an X-ray diffractometer using nickel-filtered copper radiation.

Results

10. The phase composition and chemical dissolution data for each of the 56 cements are shown in Tables B1 through B6. Table B1 shows a comparison of two cements from Arizona made without and with a preheater. Table B2 compares seven cements from six states that were all made with preheaters. Table B3 compares eight cements from five sources that were made with or without blast furnace slag. Table B4 shows data for 24 cements from 7 states. Table B5 compares nine Type I cements from six sources. Table B6 compares six Type II, III, and V cements from six sources. The 56 cements consist of 36 portland cements and 20 blended cements. There are 23 Type I cements, 2 that meet both Type I and Type II specifications, 8 Type II cements, 1 Type III cement, and 2 Type V cements. The 20 blended cements divide into 12 Type I cements made with fly ash, 1 made with bottom ash, 1 blend made with Type II cement and fly ash, and 6 made with blast-furnace slag.

11. Table B7 shows the type or types of C_3A in 30 of these cements and relative rankings of their amounts. The six that were not ranked did not contain enough

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* A times 0.1 is nanometres.

C_3A to make this type of separation. They included RC-705 (Alabama), RC-737 (Texas), RC-754 (Colorado), RC-755 (Canada), RC-764 (Arizona), and RC-832 (Colorado).

Discussion

12. Limited study of the tabulated data was made. This indicated that where direct comparisons were possible such as Table B1 for the effect of a preheater, there was no detectable effect on phase composition or phase forms. While the results for all of the cements show some differences in composition of the aluminoferrite or calcium aluminate cement phases or in the form of calcium or alkali sulfates plus or minus some noncement phases (i.e., quartz or calcite), the more striking point is the overwhelming similarity of the cements as judged by X-ray diffraction (XRD).

13. Selective dissolution was found to be helpful for XRD identification of less abundant crystalline phases or verification of tentative identifications based on XRD of a whole cement. Selective dissolution also was an effective method of separating blended and nonblended cements when iron blast-furnace slag was not the additive. Examination of the tables shows that ordinary portland cement usually contains 80 or more percent of phases that are soluble in maleic acid while blends will have more like 65 percent soluble material. The exception to this was the cements with slag (Table B3).

14. The type and relative amount of C_3A in a cement can be determined fairly effectively and simply by XRD and the use of selective dissolution (Table B7); this separation by crystal type is improved if maleic acid dissolution is followed by removal of sulfate compounds by ammonium chloride treatment (Appendix B-1).

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Burkes, J. P., and Buck, A. D. 1983. "Use of Selective Dissolution and X-Ray Diffraction to Determine Form of Tricalcium Aluminate in Portland Cement," Proceedings of the Fifth International Conference on Cement Microscopy, International Cement Microscopy Association, 14-17 March 1983, Nashville, Tenn., pp 247-251.

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Kantro, D. L., Copeland, L. E., Weise, C. H., and Brunauer, S. 1964. "Quantitative Determination of the Major Phases in Portland Cements by X-Ray Diffraction Methods," Journal of Portland Cement Association, Chicago, Ill., Vol 6, pp 20-40.

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Regourd, M., Chromy, S., Hjorth, L., Mortureux, B., and Guinier, A. 1973. "Polymorphisme des Solutions Solides in Sodium dans l'Aluminate Tricalcique," Journal of Applied Crystallography, Copenhagen, Denmark, Vol 6, pp 355-364.

Table B1

Composition and Chemical Data for a Pair of Type II Cements from One Source Made With and Without a Preheater

Constituents	RC-763 Made in Dry Kiln No Preheater: Sampled in 1976	RC-763 Made in Dry Kiln No Preheater: Resampled in 1979	RC-764 Made with Preheater: Sampled in 1976	RC-764 Made with Preheater: Resampled in 1979
Cement				
Alite	X	X	X	X
Belite	X	X	X	X
Aluminoferrite	C_4AF	C_4AF	C_4AF	C_4AF
Tricalcium Aluminate	n.d.*	Non-cubic	n.d.	Possible
Calcium and Other Sulfates				
Anhydrite	--**	--	--	--
Hemihydrate	--	--	Possible	Possible
Gypsum	X	X	X	X
Langbeinite	Possible	Possible	Possible	Possible
Miscellaneous				
Calcite	--	--	--	--
Quartz	X	Possible	--	--
MgO	X	X	X	X
Chemical Data				
Soluble in Maleic Acid, %	84.4	81.6	85.6	82.7
Soluble in NH_4Cl, %	n.d.	6.2	n.d.	n.d.
Insoluble, %	15.6	12.2	14.4	17.3

* Not determined.

** Indicates not detected.

Table B2

Composition and Chemical Data for Seven Portland Cements from Plants Using Preheaters

Constituents	Georgia RC-733 Type I Portland Cement	Texas RC-736 Type I,II Portland Cement	Ohio RC-746 Type I Portland Cement	Colorado RC-753 Type II Portland Cement	Colorado RC-754 Type II Portland Cement	Arizona RC-764 Type II Portland Cement	Kansas RC-770 Type I Portland Cement
Cement							
Alite	X	X	X	X	X	X	X
Belite	X	X	X	X	X	X	X
Aluminoferrite	C_4AF	C_6AF_2	C_4AF	C_4AF	C_6AF_2	C_4AF	C_4AF
Tricalcium Aluminate	Mixed Types	Non-cubic	Mixed Types	Cubic	n.d.*	Possible Non-cubic	Non-cubic
Calcium and Other Sulfates							
Anhydrite	X	X	--**	--	--	--	--
Hemihydrate	Possible	--	X	Possible	Possible	Possible	--
Gypsum	--	--	X	X	--	X	X
Langbeinite	Possible	--	Possible	--	--	Possible	--
Miscellaneous							
Quartz	Possible	X	X	Possible	--	--	--
MgO	--	X	X	--	--	X	X
$Ca(OH)_2$	Possible	Probable	--	--	--	--	Possible
Calcite	--	Possible	--	Possible	--	--	--
Dolomite	--	X	X	X	--	--	--
Chemical Data							
Soluble in Maleic Acid, %	82.6	84.4	79.4	80.7	83.3	82.7	82.0
Insoluble, %	17.4	15.6	20.6	19.3	16.7	17.3	18.0

* Not determined.
** Indicates not detected.

Table B3

Composition and Chemical Data for Eight Cements from Five Sources

Made With and Without Blast-Furnace Slag

Constituents	Common Source		Common Source			Single Source	German Slag Cements From Different Sources	
	RC-751 Type I Portland Cement	RC-752 Type IS Cement	RC-769 Type IS Cement	RC-770 Type I Portland Cement	RC-833 Type IS Cement	RC-758 Type IS Cement	USAECE-1C-1	USAECE-1C-2
Cement								
Alite	X	X	X	X	X	X	X	X
Belite	X	X	X	X	X	X	X	X
Aluminoferrite	C_4AF	C_4AF	C_4AF	C_4AF	C_4AF	C_4AF	C_4AF	C_4AF
Tricalcium Aluminate	Mixed Types	Mixed Types	Cubic	Cubic	Mixed Types	Mixed Types	Probably Noncubic	Probably Cubic
Calcium and Other Sulfates								
Anhydrite	X	X	X	--*	X	X	X	X
Hemihydrate	Possible	Possible	Possible	X	Possible	X	Possible	Possible
Gypsum	--	--	--	X	X	--	--	X
Langbeinite	--	--	Possible	--	--	--	--	--
Miscellaneous								
Calcite	X	--	Possible	--	--	X**	--	--
$Ca(OH)_2$	--	Possible	Probable	--	--	--	--	--
Dolomite	--	--	X	X	--	--	--	X
MgO	X	X	X	X	X	X	X	X
Quartz	--	Possible	--	--	Possible	--	--	X
CaO	--	--	--	--	--	--	--	X
Admixture		Slag	Slag		Slag	Slag	Slag	Slag
Quartz	--	Above	--	--	Above	--	--	Above
Magnetite	--	--	--	--	--	X	--	--
Melilite	--	--	--	--	X	X	X	--
Wollastonite	--	--	--	--	Possible	--	--	--

(Continued)

Table B3 (Concluded)

Constituents	Common Source		Common Source			Single Source	German Slag Cements From Different Sources	
	RC-751 Type I Portland Cement	RC-752 Type IS Cement	RC-769 Type IS Cement	RC-770 Type I Portland Cement	RC-833 Type IS Cement	RC-758 Type IS Cement	USAECE-1C-1	USAECE-1C-2
Chemical Data								
Soluble in Maleic Acid	84.6	78.9	86.5	81.4	83.6	78.7	44.8	84.0
Insoluble	15.4	21.1	13.5	18.6	16.4	21.3	55.2	16.0

* Indicates not detected.
** May be in slag portion.

Table B4

Composition and Chemical Data for 24 Cements from 7 States

Constituents	Common Source--Missouri				
	RC-722 Type I Portland Cement	RC-721 Type IP Cement	RC-738 Type I Portland Cement	RC-739 Type IP Cement	RC-740 Type IP Cement
Cement					
Alite	X	X	X	X	X
Belite	X	X	X	X	X
Aluminoferrite	C_4AF	C_4AF	C_4AF	C_4AF	C_4AF
Tricalcium Aluminate	Mixed Types	n.d.*	Mixed Types	n.d.	Mixed Types
Calcium and Other Sulfates					
Gypsum	X	--**	X	X	X
Hemihydrate	X	X	--	X	X
Anhydrite	X	X	X	X	X
Langbeinite	--	--	--	--	--
Miscellaneous					
MgO	X	X	X	X	X
Calcite	--	--	--	--	--
Quartz	Possible	--	Possible	In ash	--
Dolomite	X	X	X	X	X
$Ca(OH)_2$	--	--	X	X	--
Ettringite	--	--	--	--	--
Admixture		Fly ash		Fly ash	Bottom ash
Quartz		--		X	--
Mullite		--		X	--
Iron Oxide		--		X	--
Chemical Data					
Soluble in Maleic Acid, %	80.3	67.7	78.0	71.4	72.0
Soluble in NH_4Cl, %	n.d.	n.d.	7.6	n.d.	n.d.
Insoluble, %	19.7	32.3	14.4	28.6	28.0

* Not determined.
** Not detected.

(Sheet 1 of 4)

Table B4 (Continued)

Constituents	C.S.--Illinois RC-725 Type I Portland Cement	C.S.--Illinois RC-726(2) Type IP Cement	C.S.--Arizona RC-731 Type I Portland Cement	C.S.--Arizona RC-732 Type IP Cement	C.S.--Michigan RC-720 Type I Portland Cement	C.S.--Michigan RC-719 Type IP Cement	C.S.--Michigan RC-734 Type I Portland Cement	C.S.--Michigan RC-735 Type IP Cement
Cement								
Alite	X	X	X	X	X	X	X	X
Belite	X	X	X	X	X	X	X	X
Aluminoferrite	C_4AF	C_4AF	C_4AF	C_4AF	C_4AF	C_4AF	C_4AF	C_4AF
Tricalcium Aluminate	n.d.	n.d.	Noncubic	n.d.	Noncubic	Noncubic	Noncubic	Noncubic
Calcium and Other Sulfates								
Gypsum	--	--	X	X	X	X	X	X
Hemihydrate	Possible	Possible	X	Possible	X	Possible	Possible	X
Anhydrite	X	X	--	--	--	--	--	--
Langbeinite	--	--	--	--	--	--	--	--
Miscellaneous								
MgO	X	--	X	X	X	X	X	X
Calcite	--	--	Possible	Possible	Possible	--	--	Possible
Quartz	X	In ash	X	In ash	Possible	In ash	X	In ash
Dolomite	--	--	--	X	X	Possible	X	X
$Ca(OH)_2$	--	X	--	--	--	Possible	--	--
Ettringite	--	X	--	--	--	--	--	--
Admixture		Fly ash		Fly ash		Fly ash		Fly ash
Quartz		X		X		X		X
Mullite		X		X		X		X
Iron Oxide		X		X		X		X
Chemical Data								
Soluble in Maleic Acid, %	85.6	74.2	83.7	74.5	79.4	67.8	86.5	62.7
Soluble in NH_4Cl, %	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	5.5	9.1
Insoluble, %	14.4	25.8	16.3	25.5	20.6	32.2	8.0	28.2

(Continued)

(Sheet 2 of 4)

Table B4 (Continued)

Constituents	C.S.--South Carolina				C.S.--Tenn.	
	RC-716 Type I Portland Cement	RC-717 Type IP Cement	RC-729 Type I Portland Cement	RC-730 Type IP Cement	RC-741 Type I Portland Cement	RC-742 Type IP Cement
Cement						
Alite	X	X	X	X	X	X
Belite	X	X	X	X	X	X
Aluminoferrite	C_4AF	C_4AF	C_4AF	C_4AF	C_4AF	C_6A_2F
Tricalcium Aluminate	Cubic	Cubic	Cubic	Cubic	Cubic	Cubic
Calcium and Other Sulfates						
Gypsum	X	X	X	X	--	--
Hemihydrate	Possible	Possible	X	Possible	Possible	Possible
Anhydrite	X	X	--	X	X	X
Langbeinite	X	--	--	--	--	--
Miscellaneous						
MgO	X	--	--	--	X	--
Calcite	Possible	--	Possible	--	--	--
Quartz	--	--	--	--	Possible	In ash
Dolomite	--	--	--	--	X	X
$Ca(OH)_2$	--	--	--	--	--	--
Ettringite	--	--	--	--	--	--
Admixture		Fly ash		Fly ash		Fly ash
Quartz		X		X		X
Mullite		X		X		X
Iron Oxide		Possible		Possible		Possible
Chemical Data						
Soluble in Maleic Acid, %	80.2	65.5	80.4	66.4	81.4	69.9
Soluble in NH_4Cl, %	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Insoluble, %	19.8	34.5	19.6	33.6	18.6	30.1

(Continued)

(Sheet 3 of 4)

Table B4 (Concluded)

Constituents	C.S.--Texas			C.S.--Texas	
	RC-744 Type I Portland Cement	RC-745 Type IP Cement	RC-773 Type IP Cement	RC-807(A) Type I Portland Cement	RC-807 Type IP (MS) Cement
Cement					
Alite	X	X	X	X	X
Belite	X	X	X	X	X
Aluminoferrite	C_4AF	C_4AF	C_4AF	C_4AF	C_4AF
Tricalcium Aluminate	Mixed Types	Mixed Types	Cubic	Cubic	n.d.
Calcium and Other Sulfates					
Gypsum	--	--	X	X	X
Hemihydrate	Possible	Possible	Possible	--	--
Anhydrite	X	X	X	X	X
Langbeinite	--	--	--	--	--
Miscellaneous					
MgO	--	--	--	--	X
Calcite	--	--	--	--	--
Quartz	X	In ash	In ash	Possible	In ash
Dolomite	--	--	--	--	--
$Ca(OH)_2$	X	--	--	Possible	--
Ettringite	--	--	--	--	--
Admixture		Fly ash	Fly ash		Fly ash
Quartz		X	X		X
Mullite		X	--		--
Iron Oxide		--	--		--
Chemical Data					
Soluble in Maleic Acid, %	82.1	66.8	60.9	81.6	66.6
Soluble in NH_4Cl, %	n.d.	n.d.	n.d.	n.d.	n.d.
Insoluble, %	17.9	33.2	39.1	18.4	33.4

(Sheet 4 of 4)

Table B5

Composition and Chemical Data for Nine Type I Cements

Constituents	Alabama RC-714	Colorado RC-715	Common Source-Iceland RC-765	Common Source-Iceland RC-766	Norway RC-756	Norway RC-756(2)	Norway RC-761	Miss. RC-688	Penn. RC-834
Cement									
Alite	X	X	X	X	X	X	X	X	X
Belite	X	X	X	X	X	X	X	X	X
Aluminoferrite	C_4AF	C_6AF_2	C_4AF	C_4AF	C_4AF	C_4AF	C_4AF	C_6AF_2	C_6AF_2
Tricalcium Aluminate	Mixed types	Mixed types	Non-cubic	Non-cubic	Cubic	Cubic	Cubic	Mixed types	Mixed types
Calcium and Other Sulfates									
Gypsum	X	X	X	X	X	X	X	X	X
Hemihydrate	Possible	X	X	X	Possible	Possible	Possible	Possible	X
Anhydrite	--**	--	--	--	--	--	--	X	--
Langbeinite	Possible	--	--	--	--	--	--	--	--
Aphthitalite	--	--	--	--	--	--	--	--	Possible
Miscellaneous									
MgO	--	--	X	X	X	X	X	--	X
Calcite	X	Possible	Possible	Possible	--	--	--	--	--
Quartz	Possible	Possible	--	Possible	--	Possible	--	Possible	Possible
Dolomite	--	X	--	--	X	X	X	--	X
Ettringite	--	--	--	--	X	--	--	--	--
Melilite Series	--	--	--	--	Possible	X	--	--	--
Chemical Data									
Soluble in Maleic Acid, %	77.4	81.3	75.1	83.2	80.6	77.4	82.5	80.7	74.5
Soluble in NH_4Cl, %	5.4	n.d.*	n.d.	n.d.	n.d.	6.9	n.d.	6.3	n.d.
Soluble in Cold Water, %	--	--	--	14.5†	n.d.	n.d.	n.d.	n.d.	n.d.
Insoluble, %	17.2	18.7	24.9	16.8	19.4	15.7	17.5	13.0	25.5

* Not determined.
** Not detected.
† Separate sample.

Table B6

Composition and Chemical Data on Six Type II, III, and V Portland Cements

Constituents	Alabama RC-705 Type II Portland Cement	New York RC-831 Type II Portland Cement	Wash. RC-718 Type I-II Portland Cement	Texas RC-737 Type III Portland Cement	Colorado RC-832 Type V Portland Cement	Canada RC-755 Type V Portland Cement
Cement						
Alite	X	X	X	X	X	X
Belite	X	X	X	X	X	X
Aluminoferrite	C_4AF	C_4AF	C_6AF_2	C_6AF_2	C_6AF_2	C_4AF
Tricalcium ..luminate	--**	Non-Cubic	Non-Cubic	n.d.*	n.d.	n.d.
Calcium and Other Sulfates						
Gypsum	--	--	X	--	X	--
Hemihydrate	Possible	X	X	Possible	Possible	X
Anhydrite	X	--	--	X	--	--
Langbeinite	X	--	--	--	--	--
Miscellaneous						
MgO	X	--	X	--	Possible	X
Calcite	--	--	Possible	--	--	--
Quartz	--	Possible	X	X	--	--
Dolomite	X	Possible	--	--	--	X
CaO	--	--	--	--	--	Possible
Chemical Data						
Soluble in Maleic Acid, %	84.6	83.6	86.6	84.9	85.2	
Soluble in NH_4Cl,%	n.d.	3.0	n.d.	n.d.	n.d.	
Insoluble, %	15.4	13.4	13.4	15.1	14.8	

* Not determined.
** Not detected.

Table B7

Types and Relative Amounts of C_3A in 30 Portland Cements

Ranking	Type of C_3A: Cubic*	Mixed Forms**	Non-Cubic**
Most	RC-756	RC-834	RC-765
	RC-716†	RC-715††	
	RC-729†	RC-733	
	RC-741	RC-738	
	RC-761	RC-751	
	RC-770		
Intermediate	--	RC-714	RC-718
			RC-720‡‡
			RC-766
			RC-831
Less	RC-807(A)‡	RC-688	RC-731
	RC-829‡‡	RC-722	RC-736
	RC-753††	RC-744‡	RC-772
		RC-746	
Least	RC-725	RC-763	RC-734‡‡
Total	10	11	9

*Rankings based largely on the 4.08(A) peak.

**Rankings based largely on the 4.23(A) peak.

†Both from same source.

††Note that this high alkali Type 1 (RC-715) differs from the Type I-II from this source (RC-753).

‡RC-807(A) is cubic and RC-744 is mixed; both from one source in Texas.

‡‡RC-720 and RC-734 are non-cubic while RC-829 is cubic; all are from one source in Michigan.

APPENDIX B-1

NH_4Cl Treatment to Remove Sulfate Compounds from Cement

G. S. Wong and T. B. Husbands

Equipment and chemicals

1000-ml vacuum flask

1000-ml beaker

Buchner funnel

No. 50 Whatman filter paper

Magnetic stirrer

Mettler balance

10 percent NH_4Cl (1000 ml)

Distilled H_2O

4-5 g sample (ground - 325)

Procedure

Weigh out about 4-5 g of sample using a suitable balance. Place sample in 1000-ml beaker using a ratio of about 1 g of sample to 200 ml of 10 percent NH_4Cl solution. Stir with magnetic stirrer for 45 minutes.

The solution is filtered and washed with distilled H_2O. Wash the residue three times to assure removal of chloride.

Place residue on watch glass and allow to air dry. Weigh again to determine loss in weight.

The sample is ready to be examined by X-ray diffraction.

APPENDIX C: PETROGRAPHIC EXAMINATION--ASHES, NATURAL POZZOLANS, AND SLAG

Background

1. A total of 12 fly ashes, 2 natural pozzolans, and 1 blast-furnace slag were examined primarily by X-ray diffraction to determine what crystalline phases were present in these samples. In addition, all of the 15 samples were characterized by chemical analysis and physical tests. Four of the five lignite fly ashes (AD-506, 509, 510, 513), all three of the sub-bituminous fly ashes (AD-505, 507, 512), one of the four bituminous fly ashes (AD-511), and one of the two natural pozzolans (AD-518) were also used as pozzolans in paste and mortar mixtures. The samples are identified in the tables.

Test Specimens

2. All of the 15 samples were examined by X-ray diffraction either as received or after some grinding or both.

3. Four of the fly ashes (AD-505, 510, 512, 513) were subjected to a cold water treatment to selectively dissolve soluble constituents; the amounts dissolved were determined by weighings before and after the treatment. The water-insoluble residues were then examined by X-ray diffraction. The cold water treatment was done by placing 2 g of sample in 800 ml of distilled water that was kept cold with ice cubes made of distilled water for 3 hr; each sample was then filtered, washed with methanol, dried, and weighed. These residues were then treated with maleic acid for more selective dissolution; weighing was again used to determine the amount of sample dissolved; the insoluble residues were examined by X-ray diffraction.

4. Fly ashes AD-506, 507, 509, 511, 517, and 577 were subjected to the maleic acid treatment without the cold water treatment. Weight loss was determined as before, and the insoluble residues were examined by X-ray diffraction. The maleic acid treatment consisted of confining 5 g of sample with a solution of 25 g of maleic acid in 125 cc of methanol, followed by mixing for 30 minutes, vacuum filtration, washing with methanol four times, drying, and weighing. The samples that had been pretreated with cold water were not 5-g samples. The maleic acid treatment that was used was modified slightly from that described for cements by Mander, Adams, and Larkin (1974).*

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* Mander, J. E., Adams, L. D., and Larkin, E. E. 1966. "A Method for the Determination of Some Minor Compounds in Portland Cement and Clinker by X-Ray Diffraction," Cement and Concrete Research, Vol 4, pp 533-544.

5. The blast-furnace slag AD-537 was treated with maleic acid with weighings and subsequent X-ray diffraction examination just like the fly ashes.

6. The three subbituminous fly ashes (AD-505, 507, 512) and four of the five lignite fly ashes (AD-506, 509, 510, 513) were mixed with small amounts of distilled water and placed in drink cups to determine if they would harden. The mixtures were then examined by X-ray diffraction after they were about 21 days old.

7. The same seven subbituminous and lignite ashes plus the bituminous ash AD-511 and the natural pozzolan AD-518 were treated by a variation of CRD-C 128* as described by Pepper and Mather (1959)** as a measure of preventing excessive expansion in concrete; after thorough washing to remove all traces of sodium hydroxide, the residues were examined by X-ray diffraction.

8. All X-ray patterns were made with an X-ray diffractometer using nickel-filtered copper radiation.

9. Fly ash AD-513 and the natural pozzolan were examined by scanning electron microscopy (SEM).

Results

10. The phase identifications that were made by X-ray diffraction procedures along with some of the chemical analytical data and selective dissolution results are shown in Tables C1 through C6 for the 15 samples. Experience has shown that fly ash from bituminous coal typically contains small amounts of quartz, mullite, hematite, and magnetite as the crystalline phases. Occasionally mullite may be absent. These ashes do not harden when mixed with water. Table C3 shows the phase composition of bituminous ashes AD-511 and AD-570 along with solubility data for AD-511.

11. Experience has also shown that fly ash from subbituminous coal or lignite typically contains more and different kinds of crystalline phases than the ash from bituminous coal. Lime (CaO), anhydrite ($CaSO_4$), and periclase (MgO) are commonly found in addition to the phases usually found in bituminous ash. Tables C1 and C2 show the comparative phase composition of three subbituminous ashes (AD-505, 507, 512) and four lignite ashes (AD-506, 509, 510, 513) as well as other data. Only ashes AD-506 and AD-512 of these seven did not harden when mixed with water. Chemically determined lime ranged from 4.8 to 29.9 percent; the amount of crystalline lime by X-ray diffraction generally agreed with the chemically determined amounts; when these did not agree this was taken to mean that some of the calcium was dissolved in the glassy phase of

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* US Army Engineer Waterways Experiment Station. 1949 (Aug). Handbook for Concrete and Cement, with quarterly supplements, Vicksburg, Miss.

** Pepper, L., and Mather, B. 1959. "Effectiveness of Mineral Admixtures in Preventing Excessive Expansion of Concrete Due to Alkali-Aggregate Reaction," ASTM Proceedings, Philadelphia, Pa., Vol 59, pp 1178-1203.

the ash rather than being present as lime. As indicated earlier each table indicates which ashes contain the most, least, and intermediate amounts of the different crystalline phases as judged by the intensity of X-ray diffraction peaks.

12. As the amount of a crystalline phase in a mixture decreases or is masked by large amounts of amorphous material (glass), a point is reached where only the strongest X-ray diffraction peak of a crystalline phase may be detectable. In such cases identification of a phase may rest solely on that peak. This is the situation that exists or is approached with samples such as these 15. The basic intent of the selective dissolution chemical treatments used was to concentrate some phases and remove others as a basis for better identification of crystalline phases and as an approach to determining amounts by weight changes. Inspection of X-ray diffraction patterns of residues after the cold water treatment indicated this treatment was not worthwhile in obtaining the results just discussed. Maleic acid treatments were somewhat better as an approach to improved phase identification by X-ray diffraction. Bearing in mind the problems discussed about phase identification by X-ray diffraction in such materials note that calcium aluminoferrite is indicated as being present in the lignite ash AD-510 (Table C2); this is the same material found in most portland cements. Tetracalcium trialuminate sulfate is also indicated as being present in the same ash and possibly in the lignite ash AD-513; this is the expansive component in Type K expansive cement. AD-510 had the most lime by chemical analysis (29.9 percent) and was the most complex of the 12 ashes examined. There was probably some crystalline material in it that remained unidentified; this may also be true for a few of the other ashes. A chemical procedure for the selective removal of glassy material from fly ash has been published.*

13. The fact that ettringite was found in the hydrated material of all seven of the ashes shown in Tables C1 and C2 by X-ray diffraction is taken as proof that these and probably other ashes are a source of alumina to make ettringite with or without portland cement when they are combined with water. The fact that thenardite (Na_2SO_4) was identified in the X-ray patterns of hydrated AD-505, 509, and 510 and not in them without hydration indicates sodium was readily soluble from the glass since none of the crystalline phases identified should provide a source of sodium; the sulfate came from the anhydrite. Neither hydration nor chemical dissolution treatments had much effect on the periclase in the samples; this suggests the periclase tends to be dead burned and therefore unreactive.

14. Table C4 shows the phase identifications and some solubility data for two bituminous (AD-517, WES-44F-73) ashes and one lignite (AD-577) ash. They show the expected compositions and range of solubility data.

15. Table C5 shows phase identifications and some solubility data for two natural glassy pozzolans (AD-516, AD-518).

16. Table C6 shows phase identifications and some solubility data for blast-furnace slag (AD-537); the phases shown are normal for such material.

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* Buck, A. D., Husbands, T. B., and Burkes, J. P. 1983 (May). "Studies of the Constitution of Fly Ash Using Selective Dissolution," Miscellaneous Paper SL-83-5, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

17. Typical particle shapes of fly ash AD-513 and of natural pozzolan AD-518 are shown in Micrograph C1. Micrograph a. shows the generally larger spherical shape of fly ash particles as compared to silica fume spheres. Micrograph b shows the nonspherical and larger particle shape of this natural pozzolan as compared to both fly ash and silica fume.

Conclusions

18. Several conclusions appear warranted from the results that were obtained:

a. Fly ashes resulting from the burning of lignite and subbituminous coals are significantly different from those obtained by burning bituminous coal.

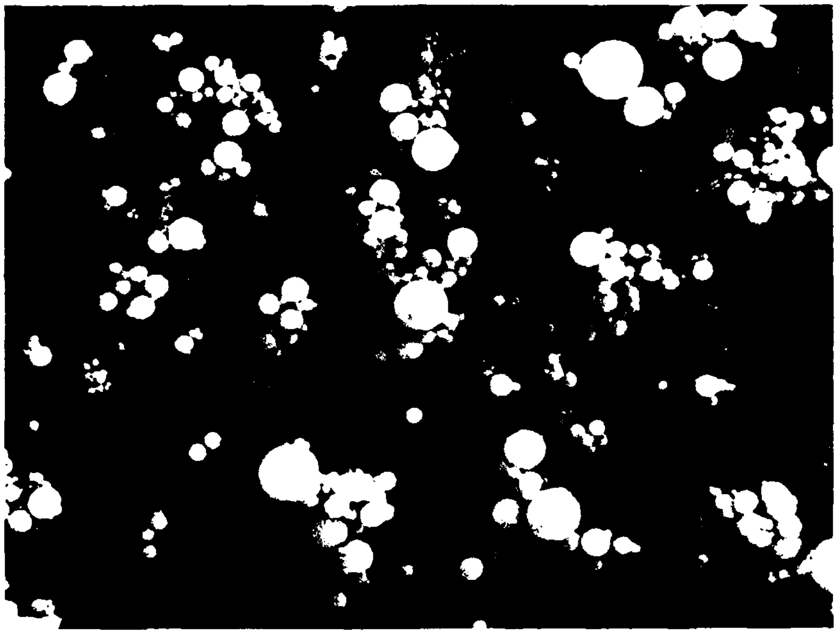
b. The lignite and subbituminous ashes are likely to be similar in phase composition and will contain more and different crystalline phases than bituminous ash.

c. The lignite and subbituminous ashes are likely to contain crystalline lime, anhydrite, and periclase in addition to the mullite, quartz, hematite, and magnetite that are usually common to all ashes.

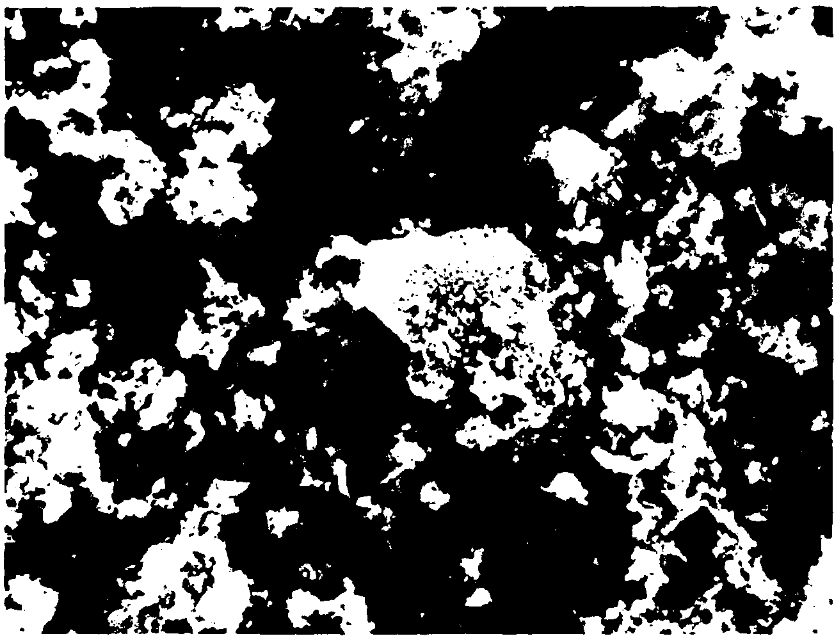
d. If an ash contains crystalline lime, it will probably harden when combined with water.

e. Since it has been observed that hydration of these lignite and subbituminous ashes resulted in the formation of ettringite and since there was no other source of aluminum, it follows that the aluminum needed to make ettringite came from the glassy phase of these ashes.

f. The one fly ash (AD-513) and the one natural pozzolan (AD-518) that were examined by SEM showed the typical spherical and nonspherical particle shapes, respectively, that were expected for these materials.



a. Fly ash AD-513, showing spherical shapes, X 2000, No. 042677-3. Largest sphere is about 5 μm in diameter.



b. Natural pozzolan AD-518, X 1000. No. 102076-15. Nonspherical shapes. Largest particle is about 35 μm.

Micrograph C1

Table C1

Compositional* and Partial Chemical Data for Three Subbituminous Fly Ashes

Crystalline Phases	AD-505** Missouri	AD-507** Missouri	AD-512** Iowa
Mullite	X (2)	X (1)†	Not detected
Quartz	X (2)	X (1)	X (2)
Hematite	X (2)	X (1)	X (2)
Magnetite	X (2)	X (1)	X (3)
Lime	X (2)	Not detected	X (1)
Hydrated Lime	X (2)	Not detected	X (1)
Periclase	X (2)	Not detected	X (1)
Anhydrite	X (2)	X (3)	X (1)
Chemical Data			
Lime, %	11.1	4.8	20.3
Soluble in Cold Water, %	5.7	Not determined	10.7
Balance Soluble in Maleic Acid, %	7.2	Not determined	11.2
Total Soluble in Maleic Acid, %	Not determined	6.0	Not determined
Insoluble	87.1	94.0	78.1
Total, %	100.0	100.0	100.0
Material Hardened in Water	Yes	Yes	No
CRD-C 128 data††			
Sc (millimoles/ℓ)	32	208	15
Rc (millimoles/ℓ)	388	398	436

* Based on X-ray diffraction data.

** Hydration of the material with water for 21 days resulted in the development of ettringite. AD-505 developed a white crust of thenardite.

† Numbers in parentheses refer to amount of a compound with one being most and three least.

†† 12.5-g sample in 25 ml of 1N NaOH at 80°C for 24 hr.

Table C2

Compositional* and Partial Chemical Data for

Four Lignite Fly Ashes

Crystalline Phases	AD-506** Texas	AD-509** North Dakota	AD-510** Minnesota	AD-513** Colorado
Mullite	X (1)†	Not detected	Possible	X (2)
Quartz	X (1)	X (2)	X (4)	X (3)
Hematite	X (2)	X (2)	X (1)	X (2)
Magnetite	X (2)	X (2)	X (1)	X (2)
Lime	X (2)	Possible (4)	X (1)	X (3)
Hydrated Lime	X (1)	Not detected	Not detected	Not detected
Periclase	X (2)	X (2)	X (1)	X (2)
Anhydrite	X (3)	X (3)	X (1)	X (2)
Melilite Group	Not detected	X	X	X
Calcium Alumino-ferrite	Not detected	Not detected	X (1)	Not detected
Tetracalcium Tri-aluminate Sulfate	Not detected	Not detected	X (1)	Possible (2)
Plagioclase Feldspar	Not detected	Not detected	Not detected	X (1)
Chemical Data				
Lime, %	19.8	13.1	29.9	21.0
Soluble in Cold Water, %	Not determined	Not determined	14.8	6.8
Balance Soluble in Maleic Acid, %	Not determined	Not determined	23.6	14.7
Total Soluble in Maleic Acid, %	13.5	12.1	Not determined	Not determined
Insoluble, %	86.5	87.9	61.6	78.5
Total	100.0	100.0	100.0	100.0
Material Hardened in Water	No	Yes	Yes	Yes
CRD-C 128 data††				
Sc (millimoles/ℓ)	44	157	9	6
Rc (millimoles/ℓ)	658	324	307	528

* Based on X-ray diffraction data.

** Hydration with water for about 21 days resulted in the development of ettringite. AD-509 and AD-510 also formed a white crust of thenardite.

† Numbers in parentheses refer to amount of a compound with one being most and four being least.

†† 12.5 g of sample in 25 ml of 1N NaOH at 80°C for 24 hours.

Table C3

Compositional* and Partial Chemical Data for

Two Bituminous Fly Ashes

Crystalline Phases	AD-511 Georgia	AD-570 Mississippi
Mullite	X (2)**	X (1)
Quartz	X (2)	X (1)
Hematite	X (2)	X (1)
Magnetite	X (1)	X (2)
Chemical Data		
Total Soluble in Maleic Acid, %	4.9	Not determined
Insoluble, %	95.1	Not determined
Total, %	100.0	
CRD-C 128 data†		
Sc (millimoles/ℓ)	162	Not determined
Rc (millimoles/ℓ)	423	Not determined

* Based on X-ray diffraction data.

** Numbers in parentheses refer to amount with one being most and two being least.

† 12.5 g of sample in 25 ml of 1N NaOH at 80°C for 24 hours.

Table C4

Compositional* and Partial Chemical Data for

Two Bituminous and One Lignite Fly Ashes

Crystalline Phases	AD-517** Michigan	WES-44F-73 Missouri	AD-577+ Texas
Mullite	X	X	X
Quartz	X	X	X
Hematite	X	X	X
Magnetite	X	X	X
Lime	X	X	X
Periclase	Not detected	Possible	X
Anhydrite	Not detected	X	X
Chemical Data			
Total Soluble in Maleic Acid, %	2.5	Not determined	8.1
Insoluble, %	97.5	Not determined	91.9
Total, %	100.0		100.0

* Based on X-ray diffraction data.

** Used in blended cement RC-719.

\+ Used in blended cement RC-807(A).

Table C5

Compositional* and Partial Chemical Data for

Two Natural Pozzolans

Crystalline Phases	AD-516 Greece	AD-518 California
Quartz	X (2)	X (1)**
Plagioclase and Potassium Feldspars	X (plagioclase only) (1)	X (2)
Cristolzalite	Not detected	X
Hematite	Not detected	X
Magnetite	Not detected	X
Biotite Mica	Not detected	X
Gypsum	Not detected	X
Calcite	X	Not detected
Dolomite	X	Not detected
Clay, 14A (1.4 nm)	X	Not detected
Chemical Data		
CRD-C 28 data†		
Sc (millimoles/ℓ)	Not determined	1055
Rc (millimoles/ℓ)	Not determined	470

* Based on X-ray diffraction data.

** Numbers in parentheses refer to amount of a compound with one being most and two being least.

† 12.5 g of sample in 25 ml of 1N NaOH at 80°C for 24 hours.

Table C6

Compositional* and Partial Chemical Data for

One Blast-Furnace Slag

Crystalline Phases	AD-537** Michigan
Monticellite	X
Melilite Series	X
Meruinite	X
Calcite	X
Iron	X
Chemical Data	
Soluble in Cold Water, %	3.1
Balance Soluble in Maleic Acid, %	56.9
Insoluble, %	40.0
Total, %	100.0

* Based on X-ray diffraction data.
** Used in iron blast-furnace slag cement RC-758.

APPENDIX D: PETROGRAPHIC EXAMINATION--FUMES

Background

1. Silica fumes and fumes of other metals are fine powders that are by-products of producing elemental silicon or ferrosilicon. They are characterized by extremely high surface area, by being glassy spheres, and by high silica contents, usually over 80 percent. A group of 16 fumes from 8 different states was examined primarily by X-ray diffraction to determine what crystalline phases were present.

Samples

2. The identification and source of each sample is shown in Tables 1 and 2. AD-536(2) was used extensively in several ongoing research programs; testing of the other 15 samples was limited to petrographic examination, chemical analysis, and some physical testing.

Test Procedure

3. A composite of each sample was examined by X-ray diffraction, usually without grinding. In addition, four of the samples were selected for additional examination. This consisted of wet sieving a portion of AD-536(2), AD-544(75), AD-545, and AD-550 over a 45 μm (No. 325) sieve. The material larger than 45 μm from each of these samples was tested with a magnet. If there were significant amounts of magnetic material (AD-545) then the material larger than 45 μm was separated into magnetic and non-magnetic portions and each was examined by X-ray diffraction. The coarser fractions of AD-536(2), AD-544(75), and AD-550 were ground and examined by X-ray diffraction without magnetic separation.

4. A portion of AD-550 was placed in distilled water overnight to dissolve soluble material. The water was then decanted and dried; the resulting solids were examined by X-ray diffraction.

5. A sample of AD-536(2) was treated by a variation of test method CRD-C 128* as described by Pepper and Mather (1959)** as a measure of preventing excessive expansion in concrete.

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* US Army Engineer Waterways Experiment Station. 1949. "Handbook for Concrete and Cement," with quarterly supplements, Vicksburg, Miss.

** Pepper, L., and Mather, B. 1959. "Effectiveness of Mineral Admixtures in Preventing Excessive Expansion of Concrete Due to Alkali-Aggregate Reaction," ASTM Proceedings, Philadelphia, Pa., Vol 59, pp 1178-1203.

6. All X-ray examinations were made with an X-ray diffractometer using nickel-filtered copper radiation.

7. A portion of several samples was prepared as an immersion mount and examined with a polarizing microscope to verify that the sample was glassy and for other features.

8. Each sample was examined by X-ray emission spectroscopy to determine if any elements had been overlooked during the regular chemical analysis.

9. A limited examination of the fume was made with a scanning electron microscope (SEM). This included the original sample (AD-536) and the third sample (AD-536(2)) from the same source; all were similar.

Results

10. The X-ray diffraction patterns indicated that all 16 of the fume samples were largely amorphous material. The silica content of these samples ranged from 42.6 percent for AD-545 to 95.2 percent for AD-541 (Tables D1 and D2). Seven samples had silica contents above 90 percent, four were between 75 and 90 percent, and five were below 75 percent (Tables D1 and D2). These usually high silica contents coupled with the appearance of the material when viewed with a polarizing microscope indicated that the amorphous material in the samples was wholly or largely silica. As indicated earlier, several different shipments of the AD-536 fume were essentially identical.

11. Four of the samples (AD-545, AD-546, AD-549, AD-557) had much higher iron contents as judged by background intensity of the X-ray charts and by chemical analysis. These four samples are grouped in Table D1; their iron contents ranged from 6.2 to 14.6 percent. While the iron contents of the other 12 samples are not shown in Table D2, they ranged from 0.0 to 0.6 percent for six of them and from 1.0 to 1.9 percent for the remaining six samples.

12. The identification of crystalline phases is shown for the four high iron samples in Table D1 and for the remaining 12 samples in Table D2. It should be kept in mind that even though many phases may be indicated, as for example AD-545 in Table D1, the combined total amount of crystalline phases in a sample was usually low because the samples were largely amorphous silica. Magnetite, quartz, silicon, and silicon carbide were the crystalline phases that were most commonly found. The chlorides sylvite and halite were present in AD-544(75), AD-544(98), AD-550, and AD-558 (Table 2); sylvite was probably present in AD-557 (Table D1) and possibly present in AD-542 (Table D2). AD-558 and AD-550 contained 1.1 and 4.1 percent chloride, respectively. The identification of these materials in AD-550 was proven by their enhanced presence in the water-soluble residue that was examined by X-ray diffraction. AD-550 also had the most crystalline material in it as judged by the X-ray diffraction peaks.

13. Two SEM micrographs of two different shipments of AD-536 fume are shown in Micrograph D1. Initial specimen preparations did not disperse the particles well as can be seen in Micrograph D1a. Modification of sample preparation using an ultrasonic cleaner gave better particle dispersion as shown in Micrograph D1b. In both micrographs the shape and small size of the spheres is evident. The largest spheres shown are about 0.5 μm or less in diameter which shows the small particle size of this material.

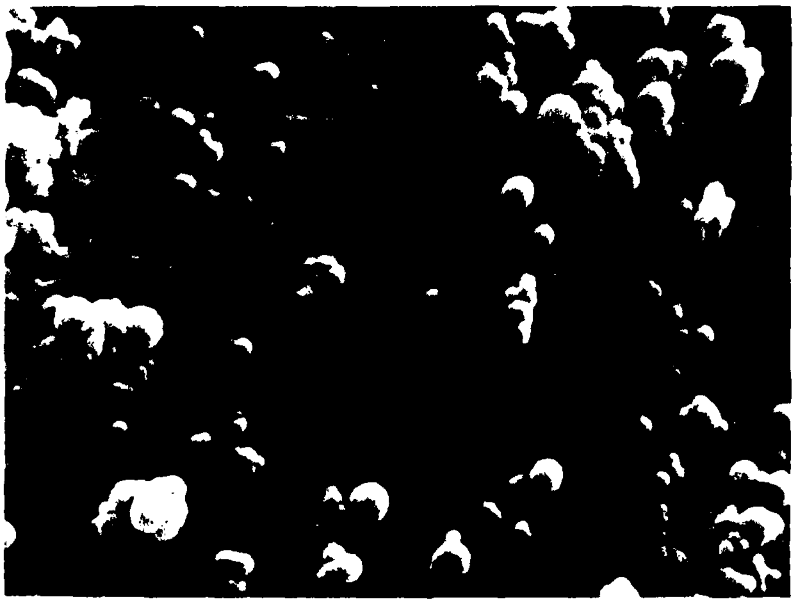
Conclusions

14. Examination of 16 by-product fume materials by X-ray diffraction along with other data indicated they were largely amorphous silica. The most significant difference found in this examination of the 16 fumes was that 4 were characterized by high iron contents while the remaining 12 fumes had much lower iron contents.

15. The chloride phases found in several samples were probably contamination.

16. Silica fumes AD-536 and AD-536(2) were shown to consist of spherical particles generally less than 0.5 μm in size. It is considered probable that the other fumes were similar.

a. Silica fume AD-536; not well dispersed.
No. 110376-29, X 10,000



b. Better dispersion of different shipment of same fume
(AD-536(2)), X 20,000. No. 072083-16

Micrograph D1

Table D1

Compositional* and Partial Chemical Data for

Four High Iron Glassy Fumes

Minor Crystalline Phases	AD-545** Ferrosilicon and Manganese Silicon Fume, Tenn.	AD-546 Ferrosilicon Fume, W. Va.	AD-549 Silica Fume, Ala.	AD-557 Ferrosilicon Fume, Ala.
Oxides				
Hematite	X	--	--	X
Magnetite	X	X	X	X
Ilmenite	X	--	--	--
Jacobsite	X	--	--	--
Quartz	X	--	X	X
Cristobalite	X	--	--	--
Manganosite	X	--	--	--
Elements				
Carbon	X	--	possible	X
Silicon	X	--	--	X
Iron	--	X	X	probable
Sulfides				
Pyrite	X	--	--	--
Pyrrotite	X	--	--	--
Silicates				
Akermanite	X	--	--	--
Gehlenite	X	--	--	--
Mullite or Sillimanite	X	--	--	--
Silicon Carbide	--	possible	X	X
Iron Silicide	--	possible	X	X
Calcite	--	--	X	--
Sylvite	--	--	--	probable
Chemical Data				
Fe_2O_3, %	6.2	13.9	11.3	14.6
SiO_2, %	42.6	73.7	67.4	71.2
Cl^-, %	0.0	0.1	0.0	0.2

* All identifications are based on X-ray diffraction; most identifications are tentative since they are usually based on one or at most only a few peaks.

** Identifications based on examination of material coarser than a 45-μm (No. 325) sieve as well as of the whole sample.

Table D2

Compositional* and Partial Chemical Data for

Twelve Glassy Fumes

Minor Crystalline Phases	AD-536(2)** Silica Fume, Ala.	AD-541 Silica Fume, Ohio	AD-542 Silica Fume, Ohio	AD-543 Silica Fume, Ore.	AD-544(75)** Silica Fume, Wash.	AD-544(98) Silica Fume, Wash.
Oxides						
Magnetite	--	X	X	X	X	X
Spinel Group	--	Possible	Possible	--	--	X
Quartz	X	Possible	Possible	X	X	X
Cristobalite	--	--	--	--	X	X
Elements						
Carbon	--	Possible	Possible	Possible	--	X
Silicon	--	X	X	--	X	X
Plagioclase Feldspar	--	--	--	--	X	--
Silicon Carbide	X	X	X	X	X	X
Iron Silicide	--	--	--	--	Possible	--
Barium Ferrite (IV)	--	--	--	--	Possible	--
Chlorides						
Sylvite	--	--	Possible	--	X	X
Halite	--	--	--	--	X	X
Chemical Data						
SiO_2, %	93.9	95.2	89.4	92.6	90.1	83.6
Cl^-, %	0.0	0.0	0.2	0.0	0.1	0.2
CRD-C 128 data†						
Sc (millimoles/ℓ)	1544	Not determined				
Rc (millimoles/ℓ)	378	Not determined				

(Continued)

* Based on X-ray diffraction data; most identifications are tentative since they are usually based on one or at most only a few peaks.

** Identifications based on examination of material coarser than a 45-μm (No. 325) sieve as well as of the whole sample.

† 12.5 g of sample in 25 ml of 1N NaOH at 80°C for 24 hours.

Table D2 (Concluded)

Minor Crystalline Phases	AD-548 Silica Fume, Ky.	AD-550** Mixture of Chromium, Manganese, and Ferro-Silicon Fume, Ohio	AD-551 Silica Fume, Ohio	AD-552 Ferro-Silicon Fume, New York	AD-553 Ferro-Chrome and Silica Fume, New York	AD-558 Ferro-Silicon Fume, Wash.
Oxides						
Magnetite	X	X	X	X	X	X
Spinel Group	--	X	X	--	X	--
Quartz	--	X	X	--	X	X
Elements						
Carbon	--	X	X	--	Possible	X
Silicon	--	--	--	--	X	X
Plagioclase Feldspar	--	X	--	--	--	--
Olivine	--	X	--	--	--	--
14-A Clay	--	Possible	--	--	--	--
Calcite	--	X	--	--	--	--
Silicon Carbide	X	--	X	X	X	X
Chlorides						
Sylvite	--	X	--	--	--	X
Halite	--	X	--	--	--	X
Chemical Data						
SiO_2, %	91.5	67.4	93.6	93.3	80.7	85.1
Cl, %	0.1	4.1	0.0	0.1	0.1	1.1

* Based on X-ray diffraction data; most identifications are tentative since they are usually based on one or at most only a few peaks.

** Identifications based on examination of material coarser than a 45-μm (No. 325) sieve and of water-soluble material as well as of the whole sample.

APPENDIX E: METHODS OF CHEMICAL ANALYSIS

(A) Method of Analysis of Portland Cement and Portland Blast-Furnace Slag Cements Using Flame Atomic Absorption (AA)

1. Summary of method.

The cement is combined with ammonium chloride and digested in hydrochloric acid; silica is removed by filtration. The filtrate is diluted to 500 ml and analyzed for Al, Fe, Mg, Mn, Ti, Na, and K by AA.

2. Reagents.

2.1 Ammonium chloride (NH_4Cl), crystals, reagent grade.

2.2 Hydrochloric acid (HCl), reagent grade.

2.3 SRM cements - National Bureau of Standards, Standard Reference Cements, SRM's 633-639.

2.4 Standard cement solutions. Remove SiO_2 and reserve the filtrate in a 500-mL volumetric flask according to ASTM C 114 (Silicon Dioxide). Dilute the filtrate to mark in the flask and mix. Prepare the complete series of SRM's 633-639.

3. Equipment.

3.1 Steam bath.

3.2 500-ml volumetric flask.

3.3 Any type of AA instrument that can be demonstrated to give the degree of accuracy and precision as indicated in ASTM C 114 (Number of Determinations and Permissible Variations).

4. Procedure.

4.1 Follow ASTM C 114 (Reference Methods).

4.2 Catch the filtrate from the filtering of the silica determination in a 500-mL flask. Dilute to mark and mix.

4.3 Read the absorbance or percent of the element as an oxide on the AA instrument using the SRM cement solutions as standards; convert to percent.

4.4 Calculations. Absorbance to percent oxide

$$E_c = \frac{A_a - A_c}{A_b - A_a} (E_a - E_b) + E_a$$

where. A_a = Absorbance reading of standard that is lower than unknown.
A_b = Absorbance reading of standard that is higher than unknown.
A_c = Absorbance reading of the unknown.
E_a = Percent oxide of standard A_a.
E_b = Percent oxide of standard A_b.
E_c = Percent oxide of unknown.

(B) Method of Analysis of Elements Using Flame Atomic Absorption (Portland-Pozzolan Cements and Pozzolans)

Method of Analysis

1. Summary: The sample of portland-pozzolan cement or pozzolan was fused with lithium metaborate ($LiBO_2$) and dissolved in an acid solution. The solution was analyzed by flame atomic absorption using standards.

2. Reagents.

2.1 Lithium metaborate ($LiBO_2$) reagent grade. Analyze the $LiBO_2$ for the elements that will be determined in the blended cements or pozzolans. If more than a trace is found of any element, reject the $LiBO_2$.

2.2 HCl - concentrated reagent grade.

2.3 Silica flour, at least 99.9 percent pure.

2.4 Cements - SRM, National Bureau of Standards Reference Materials, SRM 633-639.

2.5 Standard solutions of SiO_2 and SRM Cements.

Blend 0.5 g $\pm$ 0.5 mg of SiO_2 or a SRM cement with 1 g $LiBO_2$. Place 0.1 g $LiBO_2$ in bottom of a prefired carbon crucible. Place the blended mixture on top of the $LiBO_2$ in the crucible and 0.1 g $LiBO_2$ that is used as a chemical rinse of the blending on top. Fuse for 15 min at 1100° C. Remove the fused, melted, mass from the furnace. Gently swirl and pour the melt into a 250-ml plastic beaker containing 5 ml concentrated HCl and 50 ml water. Stir with a magnetic stirrer until the fusion is dissolved; usually less than 10 min. Transfer to a 500-ml volumetric flask and rinse the plastic beaker at least three times with ambient temperature water. Dilute the contents of the flask to mark and mix.

2.6 Equipment.

2.6.1 Carbon crucible, 8-ml capacity, made from purified graphite.

2.6.2 Furnace capable of maintaining 1100° C $\pm$ 25° C.

2.6.3 Magnetic stirrer with Teflon-coated stirring bars.

2.6.4 Plastic beaker, 250-ml capacity with lip.

2.6.5 Volumetric flask, Class A, 500 ml with stopper.

2.6.6 Any type of AA instrument that will be within the accuracy and precision as defined in the following paragraph.

For determining the accuracy and precision, use at least one SRM cement (633-639) solution that will have close to the same percent of the element as the unknown samples. The SRM must read within the permissible variation of ASTM C 114, Table I.

The parameters for the use of the Perkin-Elmer 306, Flame Spectrophotometer that was used in this study are shown on the next page.

3. Procedure.

3.1 Prepare the sample the same way as the standard samples were prepared.

AA Operating Parameters, Perkin-Elmer 306 Flame Spectrometer

	Wavelength	Slit Setting	Flame Type	Burner
Aluminum	309.3-UV	4 (0.7 nm)	N_2O - Acetylene Reducing (rich red)	2-in. path
Iron	248.3-UV	3 (0.2 nm)	Air - Acetylene Oxidizing (lean blue)	4-in. path
Magnesium	285.2-UV	4 (0.7 nm)	Air - Acetylene Oxidizing (lean blue) or NO_2 - Acetylene (rich red)	4-in. path 2-in. path
Manganese	279.5-UV	3 (0.2 nm)	Air - Acetylene Oxidizing (lean blue)	4-in. path
Potassium	766.5-(383 Vis)	4 (1.4 nm)	Air - Acetylene Oxidizing (lean blue)	4-in. path
Sodium	589.0-(295 Vis)	4 (1.4 nm)	Air - Acetylene Oxidizing (lean blue)	4-in. path
Titanium	365.3-UV	3 (0.2 nm)	N_2O - Acetylene Reducing (rich red)	2-in. path
Silicon	251.6	3 (0.2 nm)	NO_2 - Acetylene Reducing (rich red)	2-in. path
Calcium	423 (211 Vis)	4 (0.7 nm)	Air - Acetylene Oxidizing (lean blue) NO_2 - Acetylene (rich red)	4-in. path 2-in. path

3.2 Read either the absorbance or as percent oxide of the element on the AA instrument using SRM cement solution standards as standards for all the elements except silica for silica fumes that are above 70 percent SiO_2. For these fumes use SiO_2 solutions and dilute as needed.

3.3 Calculation of absorbance to percent oxide

$$E_c = \frac{A_a - A_c}{A_b - A_a} (E_a - E_b) + E_a$$

where: A_a = Absorbance reading of standard that is lower than unknown.
A_b = Absorbance reading of standard that is higher than unknown.
A_c = Absorbance reading of the unknown.
E_a = Percent oxide of standard A_a.
E_b = Percent oxide of standard A_b.
E_c = Percent oxide of unknown.

(C) Method of Iron Analysis for Silica Fumes by Titration with Standard Solution of Potassium Dichromate

1. Summary of Method. The silica fume is fused with $LiBO_2$ and iron (III) is reduced to iron (II) with stannous chloride (SnCl) and titrated with a standard solution of potassium dichromate ($K_2Cr_2O_7$). This determination is not affected by any titanium or vanadium that may be present in the pozzolan or cement.

2. Reagents.

2.1 $LiBO_2$, reagent grade.

2.2 HCl concentrated, reagent grade.

2.3 Barium diphenylamine, sulfonate indicator solution. Dissolve 0.3 g of barium diphenylamine sulfonate in 100 ml H_2O.

2.4 Potassium dichromate, standard solution (1 ml = 0.004 g Fe_2O_3). Prepare according to ASTM C 114 (Reagents). Check the solution against known Fe_2O_3 values of pozzolans and SRM cements that are prepared by $LiBO_2$ fusions and calculate the factor.

2.5 Stannous chloride solution. Prepare according to ASTM C 114 (Reagents).

3. Apparatus and materials shall meet the requirements of ASTM C 114 (General, Apparatus and Materials).

3.1 Carbon crucible, 8-ml capacity, made from purified graphite.

3.2 Furnace capable of maintaining 1100° C $\pm$ 25° C.

3.3 Magnetic stirrer with Teflon-coated stirring bars.

3.4 150-ml Pyrex beakers with lip.

3.5 Hot plate.

3.6 Mortar and pestle.

3.7 25-ml Class A burette.

4. Procedure.

A 0.5-g $\pm$ 0.5-mg sample of silica fume is blended with 1 g $LiBO_2$ and is transferred to a carbon crucible which has 0.1 g $LiBO_2$ sprinkled in the bottom. It is covered with 0.1 g $LiBO_2$ that is used to chemically wash the mortar and pestle that was used for blending. Fuse for 15 min at 1100° C. Remove from furnace, gently swirl the melt and pour into a 150-ml glass beaker containing 10 ml concentrated HCl and 50 ml H_2O. Stir until the fusion is dissolved, usually 10 min or less. Check the crucible for any traces of fusion. If there are any, reject the fusion. Remove and rinse the stirring bar. Continue with ASTM C 114 (Ferric Oxide) and finish the analysis.

Prepare and analyze a blank similarly except put in no sample.

5. Calculations.

Calculation Fe_2O_3 to the nearest 0.01 percent.

$$Fe_2O_3 \text{ percent} = \frac{E}{W} (V-B) \times 100$$

where:

E = Fe_2O_3 equivalents of $K_2Cr_2O_7$ solution in g/ml.
V = ml of $K_2Cr_2O_7$ solution required by sample.
B = ml of $K_2Cr_2O_7$ solution required by blank determination.
W = weight of sample within 0.1 mg.

APPENDIX F: TEST REPORTS FOR MATERIALS

TO: Mrs. K. Mather Ch, Petrography & X-Ray Branch CL	REPORT OF TESTS OF PORTLAND CEMENT USAECE C-1 and C-2	FROM CORPS OF ENGINEERS U.S. ARMY Cem & Pozz Test Br CL

TEST REPORT NO WES-197-73	BIN NO	CWT REPRESENTED	DATE 24 Sep 73
SPECIFICATION		DATE SAMPLED	
COMPANY	LOCATION	BRAND	
THIS CEMENT DOES	MEET SPECIFICATION REQUIREMENTS		

SAMPLE NO	Hochofen	C-1			Eisenportland		C-2
SiO_2	27.5				24.8		
Al_2O_3 %	10.6				8.4		
Fe_2O_3 %	1.7				1.9		
MgO %	4.5				4.1		
SO_3 %	2.8				1.9		
LOSS ON IGNITION %	0.1	(2)	(3)		2.2	(2)	(3)
* ALKALIES-TOTAL AS Na_2O %	(1) 0.62	0.0208	0.091		(1) 0.81	0.157	0.143
* Na_2O %	0.24	0.0092	0.044		0.27	0.0083	0.050
* K_2O %	0.58	0.0176	0.071		0.82	0.226	0.111
INSOLUBLE RESIDUE %	0.10				1.52		
CaO %	50.6				54.8		
C_3S %							
C_3A							
C_2S %							
$C_3A + C_3S$ %							
~~xxxx~~ Specific Gravity	3.00				3.04		
$C_4AF + 2\ C_3A$ %							
HEAT OF HYDRATION, 7D, CAL/G							
HEAT OF HYDRATION, 28D, CAL/G							
SURFACE AREA SQ CM/G (A.P.)	3240				3240		
AIR CONTENT %							
COMP STRENGTH 7 D, PSI	2350				2320		
COMP STRENGTH 28 D, PSI	4400				4040		
COMP STRENGTH D, PSI							
FALSE SET-PEN. FINAL %							
SAMPLE NO.	Hochofen				Eisenportland		
AUTOCLAVE EXP. %	-0.02				0.14		
INITIAL SET, HR:MIN Gilmore	5:15				3:50		
FINAL SET, HR:MIN Gilmore	8:25				7:55		
SAMPLE NO.							
AUTOCLAVE EXP. %							
INITIAL SET, HR:MIN							
FINAL SET, HR:MIN							

REMARKS Memorandum for All Concerned No. 1896 Job No. 441-C267.14Ci41

*(1) Acid Soluble Alkali Analysis
(2) Water Soluble Alkali Analysis
(3) 28-day Alkali in water

W. G. Miller
W. G. MILLER
Chemist
Chief, Cement and Pozzolan Test Branch

ENG FORM

TO		FROM
A. D. Buck Petrography & X-Ray Br Engr Sci Div Concrete Lab	REPORT OF TESTS OF PORTLAND CEMENT	CORPS OF ENGINEERS U.S. ARMY Cement & Pozzolan Test Br Concrete Laboratory USAE WES

TEST REPORT NO. WES-68-74	B/L NO.	AMT REPRESENTED	DATE 15 Apr 74
SPECIFICATION SS-C-192g, Type I, LA		DATE SAMPLED 3 Apr. 74	
COMPANY United	LOCATION Artesia, Miss.	BRAND	

THIS CEMENT DOES X MEET SPECIFICATION REQUIREMENTS

SAMPLE NO.	1		1AA		1(AA)			
SiO_2, %	20.9				TiO_2%	0.29		
Al_2O_3, %	6.2		5.38		Mn_2O_3%	0.23		
Fe_2O_3, %	2.9		3.02		P_2O_5	0.19	(Colorimetric)	
MgO, %	0.9							
SO_3, %	2.6							
LOSS ON IGNITION, %	0.6							
ALKALIES-TOTAL AS Na_2O, %	0.44	Water Soluble	Alkali	As Na_2O%			0.16	
Na_2O, %	0.17						0.03	
K_2O, %	0.41						0.20	
INSOLUBLE RESIDUE, %	0.13							
CaO, %	65.5							
C_3S, %	54.6							
C_3A, %	11.5		9.7					
C_2S, %	18.3							
$C_3A + C_3S$, %	66							
C_4AF, %	8.76							
$C_4AF + 2C_3A$, %								
HEAT OF HYDRATION, 7D, CAL/G	85							
HEAT OF HYDRATION, 28D, CAL/G	96							
SURFACE AREA, SQ CM/G (A.P.)	3320							
AIR CONTENT, %	9.5							
COMP. STRENGTH, 3 D, PSI	2860	COMP STR, 90 D, PSI			5860			
COMP. STRENGTH, 7 D, PSI	4040	COMP STR, 180D, PSI			6050			
COMP. STRENGTH, 28 D, PSI	5320	COMP STR, 365D, PSI						
FALSE SET-PEN. F								
SAMPLE NO.	1							
AUTOCLAVE EXP., %	0.06							
INITIAL SET, HR/MIN	3:10							
FINAL SET, HR/MIN	5:05							
SAMPLE NO.								
AUTOCLAVE EXP., %								
INITIAL SET, HR/MIN								
FINAL SET, HR/MIN								

REMARKS:

Job No. 441-C145.14Cill

CF:
Mr. Tynes

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

Mrs. K. Mather
Ch, Engr Sci Div
CL

REPORT OF TESTS OF PORTLAND CEMENT

RC-688(2)

FROM CORPS OF ENGINEERS
U.S. ARMY

Cem & Pozz Test Br
Engr Sci Div
CL

TEST REPORT NO	BIN NO	CWT REPRESENTED 1 Sample	DATE 11 Feb 77
SPECIFICATION Type I		DATE SAMPLED	
COMPANY United	LOCATION Artesia, MS	BRAND	

THIS CEMENT DOES MEET SPECIFICATION REQUIREMENTS

SAMPLE NO	RC-688(2)			AA	AA			
SiO_2, %	20.0				TiO_2	0.44		
Al_2O_3, %	6.0			5.40	Mn_2O_3	0.03		
Fe_2O_3, %	2.8			2.78	P_2O_5	0.33		
MgO, %	1.1							
SO_3, %	2.6							
LOSS ON IGNITION, %	1.3							
ALKALIES-TOTAL AS Na_2O, %	0.37							
Na_2O, %	0.19							
K_2O, %	0.27							
INSOLUBLE RESIDUE, %	0.09							
CaO, %	65.8							
C_3S, %	64.4							
C_3A, %	11.1			9.6				
C_2S, %	8.9							
$C_3A + C_3S$, %	75.5							
C_4AF, %	8.4							
$C_4AF + 2C_3A$, %	30.6							
HEAT OF HYDRATION, 7D, CAL/G								
HEAT OF HYDRATION, 28D, CAL/G								
SURFACE AREA, SQ CM/G (A.P.)	3420							
AIR CONTENT, %	9.1							
COMP STRENGTH, 3 D, PSI	2830							
COMP STRENGTH, 7 D, PSI	4380							
COMP STRENGTH, D, PSI								
FALSE SET-PEN F., %								
SAMPLE NO.	RC-688(2)							
AUTOCLAVE EXP., %	0.08							
INITIAL SET, HR/MIN	2:35							
FINAL SET, HR/MIN	4:40							
SAMPLE NO								
AUTOCLAVE EXP., %								
INITIAL SET, HR/MIN								
FINAL SET, HR/MIN								

REMARKS Memorandum for Record No. 1985; Job No. 545-C530.17Ci41

THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U.S. GOVERNMENT

W. G. MILLER
Chemist
Chief, Cement and Pozzolan Test Branch

ENG FORM 1 MAR 72 6008-R

TO:		From:
Mrs. K. Mather Chief, Eng Sci Div Structures Laboratory	**REPORT OF TEST OF HYDRAULIC CEMENT** RC-688(3)	Structures Laboratory USAE Waterways Exper. Sta P. O. Box 631 Vicksburg, MS 39180

COMPANY: United Cement	BIN NO.	TEST REPORT NO. WES-154-78
LOCATION: Artesia, MS	TONS REPRESENTED:	DATE 9 May 78
SPECIFICATION: Type I		DATE SAMPLED 23 Feb 78

TEST RESULTS OF THIS SAMPLE LOT [X] COMPLY [ ] DO NOT COMPLY WITH SPECIFICATION LIMITS (SEE REMARKS)

SAMPLE NO.	RC-688(3)		AA					
SiO_2, %	20.51							
Al_2O_3, %	6.60		5.89					
Fe_2O_3, %	2.70		2.90					
CaO, %	65.34							
MgO, %	0.81							
SO_3, %	2.67							
LOSS ON IGNITION, %	0.72							
INSOLUBLE RESIDUE, %	0.18							
Na_2O, %	0.18							
K_2O, %	0.32							
ALKALIES-TOTAL AS Na_2O, %	0.39							
C_3S, %	54.3							
C_3A, %	12.9							
C_2S, %	17.8							
$C_3A + C_3S$, %	67.22							
C_4AF, %	8.22							
$C_4AF + 2C_3A$, %	34.06							
HEAT OF HYDRATION, 7D, CAL/G								
HEAT OF HYDRATION, 28D, CAL/G								
(AP) Surface Area, SQ CM/G	3420							
AIR CONTENT, %	9.2							
COMP. STRENGTH, 1 D, PSI	1410		COMP STR 14 D, PSI:			5460		
COMP. STRENGTH, 4 D, PSI	3710		COMP STR 28 D, PSI:			6030		
COMP. STRENGTH, 7 D, PSI	4390		COMP STR 90 D, PSI:			6550		
FALSE SET-PEN. F/I, %			COMP STR 180 D, PSI:			7230		
SAMPLE NO.			COMP STR 365 D, PSI:			6790		
AUTOCLAVE EXP., %	0.00							
INITIAL SET, Hr/min	2:30							
FINAL SET, Hr/min	3:55							

REMARKS Memorandum No. 1985 A; Job No. 545-C530.18Ci41

Copy furnisned: Mrs. K. Mather, Ch/Eng Sci Div (dupe)

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

WES FORM 1540, 1 SEP 84 REPLACES ENG FORM 6008-R, 1 MAR 72, WHICH IS OBSOLETE.

TO		
Mr. W. O. Tynes Chief, Conc & Rk Prop Br Engr Mech Div CL	**REPORT OF TEST OF HYDRAULIC CEMENT** RC-705	Cem & Pozz Test Br Engr Sciences Div CL

COMPANY: Citadel	BIN NO	TEST REPORT NO WES-252-74
LOCATION: Birmingham, AL	TONS REPRESENTED	DATE 30 Sept 72
SPECIFICATION: Type II, LA		DATE SAMPLED

TEST RESULTS OF THIS SAMPLE LOT XX COMPLY ___ DO NOT COMPLY WITH SPECIFICATION LIMITS (SEE REMARKS)

SAMPLE NO.	I (WET)		I (AA)		I (AA)			
SiO_2, %	[illegible]				TiO_2 %	0.18		
Al_2O_3, %	4.0		3.44		Mn_2O_3 %	0.02		
Fe_2O_3, %	4.2		4.17		P_2O_5 %	0.03	(Colormetric)	
CaO, %	62.5							
MgO, %	3.5							
SO_3, %	1.7							
LOSS ON IGNITION %	0.6							
INSOLUBLE RESIDUE %	0.26							
Na_2O %	0.12					0.01		
K_2O %	0.49					0.23		
ALKALIES-TOTAL AS Na_2O, %	0.44		Water Soluble as Na_2O%			0.16		
C_3S, %	45.6							
C_3A %	3.51		2.0					
C_2S %	30.9							
$C_3A + C_3S$, %	49.1							
C_4AF %	12.7							
$C_4AF + 2C_3A$, %	19.67							
HEAT OF HYDRATION, 7D, CAL/G	68							
HEAT OF HYDRATION, 28D, CAL/G	79							
(AP) Surface Area, SQ CM/G	3150							
AIR CONTENT %	8.4							
COMP STRENGTH, 3 D, PSI	1630		COMP STR, 90D, PSI:			5760		
COMP STRENGTH, 7 D, PSI	2280		COMP STR, 180D, PSI:			5990		
COMP STRENGTH, 28 D, PSI	4040		COMP STR, 365D, PSI:					
FALSE SET-PEN, F/I %								
SAMPLE NO	1							
AUTOCLAVE EXP., %	0.10							
INITIAL SET, Hr/Min	3:15							
FINAL SET, Hr/Min	5:45							

REMARKS

Sample received from Mr. W. O. Tynes, Job No. 441-C-342.15CC11, Lab Stock.

W. G. MILLER
Chemist
Chief, Cement and Pozzolan Test Branch

WES FORM 1 SEP 84 1540 REPLACES ENG FORM 6008-R, 1 MAR 72, WHICH IS OBSOLETE.

TO		FROM: CORPS OF ENGINEERS U. S. ARMY
Mrs. K. Mather Ch, X-Ray & Petro Engr Sciences Div CL	REPORT OF TESTS OF PORTLAND CEMENT	Cem & Pozz Test Br Engr Sciences Div CL

TEST REPORT NO. WES-31-75	BIN NO.	CWT REPRESENTED.	DATE: 10 Mar 75
SPECIFICATION:		DATE SAMPLED:	
COMPANY:	LOCATION		BRAND

THIS CEMENT DOES MEET SPECIFICATION REQUIREMENTS

SAMPLE NO.								
SiO_2, %								
Al_2O_3, %								
Fe_2O_3, %								
MgO, %								
SO_3, %								
LOSS ON IGNITION, %								
ALKALIES-TOTAL AS Na_2O, %								
Na_2O, %								
K_2O, %								
INSOLUBLE RESIDUE, %								
CaO, %								
C_3S, %								
C_3A, %								
C_2S, %								
$C_3A + C_3S$, %								
C_4AF, %								
$C_4AF + 2C_3A$, %								
HEAT OF HYDRATION, 7D, CAL/G								
HEAT OF HYDRATION, 28D, CAL/G								
SURFACE AREA, SQ CM/G (A.P.)								
AIR CONTENT, %								
COMP. STRENGTH, D, PSI								
COMP. STRENGTH, D, PSI								
COMP. STRENGTH, D, PSI								
FALSE SET-PEN. F/I %								
SAMPLE NO.								
AUTOCLAVE EXP., %								
INITIAL SET, HR/MIN								
FINAL SET, HR/MIN								
SAMPLE NO.								
AUTOCLAVE EXP., %								
INITIAL SET, HR/MIN								
FINAL SET, HR/MIN								

REMARKS: Samples received from:

RC-714 - Citadel, Demopolis, AL Type I
RC-715 - Ideal, Ft.Collins, CO Type I
RC-716 - Santee Type I
RC-717 - Santee Type 1-P
RC-718 - Lone Star, Seattle, WA Type I & II
RC-719 - Dundee, Dundee, MI Type 1-P
RC-720 - Dundee, Dundee, MI Type I
RC-721 - Dundee, Clarksville, MO Type 1-P
RC-722 - Dundee, Clarksville, MO Type I

THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U. S. GOVERNMENT

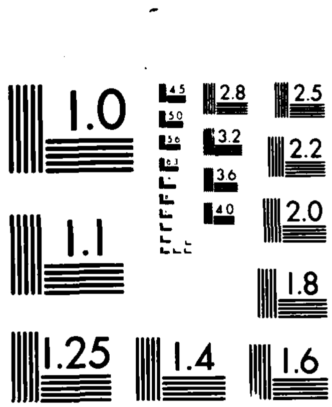
W. G. Miller
W. G. MILLER
Chemist
Chief, Cement and Pozzolan Test Branch

ENG FORM 1 MAR 72 6008-R

PREVIOUS EDITIONS OBSOLETE

AD-A171 753 VARIATIONS IN CEMENTITIOUS MEDIA(U) ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS STRUCTURES LAB R E REINHOLD ET AL. MAY 86 WES/TR/SL-86-10 3/3

UNCLASSIFIED F/G 11/2 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

CHEMICAL

SUBJECT	DATE	PAGES
WES-31-75 Memorandum No. 1953)	10 Mar 75	2

SOURCE OF DATA

COMPUTED BY	CHECKED BY	SECTION

(Type)	RC-714 I	RC-715 I	RC-716 I	RC-717 1-P	RC-718 I & II	RC-719 1-P	RC-720 I	RC-721 1-P	RC-722 I
SiO_2	19.9	20.7	20.6	24.8	22.7	25.3	21.1	24.1	20.7
R_2O_3				15.3		13.8		14.6	
Al_2O_3	7.3	5.8	5.9	11.9	4.1	9.8	5.7	10.3	5.1
Fe_2O_3	3.6	2.4	2.6	3.5	3.0	4.0	2.8	4.3	2.3
CaO	64.4	64.7	65.2	54.1	64.6	54.2	62.6	54.4	63.8
MgO	0.8	1.3	1.1	0.8	1.1	2.9	3.7	2.9	2.8
SO_3	2.5	3.1	2.8	3.1	1.9	2.6	2.6	2.4	2.9
Moist.				1.2		0.7		0.4	
Ign. Loss	0.9	1.0	1.5	1.0	1.2	1.3	1.1	0.9	1.0
Insol.	0.49	0.19	0.30	15.62	0.15	12.75	0.18	16.57	0.07
	ACID SOLUBLE ALKALIES								
Na_2O	0.14	0.31	0.08	0.08	0.76	0.27	0.32	0.07	0.09
K_2O	0.39	0.90	0.27	0.19	0.27	0.60	0.72	0.56	0.63
Total as Na_2O	0.40	0.90	0.26	0.21	0.94	0.66	0.79	0.44	0.50
	WATER SOLUBLE ALKALIES								
Na_2O	0.02	0.08	0.01	0.01	0.08	0.05	0.05	0.01	0.01
K_2O	0.19	0.62	0.08	0.04	0.10	0.25	0.31	0.31	0.26
Total as Na_2O	0.14	0.49	0.06	0.04	0.15	0.21	0.25	0.21	0.18
C_3A	13.1	11.2	11.8		5.6		10.3		9.7
C_3S	50.4	54.8	57.5		53.5		45.4		56.1
$C_3S + C_3A$	63.5	66.0	69.4		59.1		55.8		65.8
C_2S	18.9	18.0	15.8		24.7		26.2		17.0
C_4AF	11.0	7.3	7.8		9.2		8.4		7.1
$C_4AF + 2C_3A$	37.2	29.7	31.6		20.4		29.0		26.4

WES FORM NO. 1114
JANUARY 1961

PHYSICAL

SUBJECT		DATE	PAGE
WES-31-75	(Memorandum No. 1953)	10 Mar 75	3

SOURCE OF DATA

COMPUTED BY	CHECKED BY	SECTION

(Type)	RC-714 I	RC-715 I	RC-716 I	RC-717 1-P	RC-718 I & II	RC-719 1-P	RC-720 I	RC-721 1-P	RC-722 I
S.G.				2.93		2.96		3.03	
% pass.									
325 sieve				95.6		90.8		87.0	
Compressive Strengths									
3-day	3530	4330	3720	3260	2680	2680	2980	1590	3430
7-day	4480	5020	5010	4340	3540	3470	4120	2290	4680
28-day	5910	5910	6790	5880	4890	4900	5130	3650	5970
Fineness	3550	3630	3860	4100	3460	3720	3350	3250	3590
Air %	8.6	8.4	7.9	6.8	8.8	5.2	9.2	6.1	8.0
Auto Exp.	0.33	0.01	0.06	-0.04	-0.06	0.03	0.18	0.06	0.14
VICAT:									
S I	1:45	2:20	1:35	3:05	1:35	2:15	2:00	2:45	1:55
S F	4:10	4:25	4:05	5:50	3:45	4:25	4:10	4:50	4:10

WES FORM NO. 1114
JANUARY 1961

TO	REPORT OF TESTS OF PORTLAND CEMENT RC-725	FROM CORPS OF ENGINEERS U.S. ARMY Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Group P.O. Box 631 Vicksburg, MS 39180

TEST REPORT NO	B.N.NO	AMT REPRESENTED	DATE
SPECIFICATION Type I		DATE SAMPLED	
COMPANY Missouri Portland	LOCATION Joppa, IL		BRAND
THIS CEMENT DOES	MEET SPECIFICATION REQUIREMENTS		

SAMPLE NO (Analysis)	1(WET)	1(AA)		1(AA)				
SiO_2, %	20.6			TiO_2%	0.23			
Al_2O_3, %	4.6	4.3		Mn_2O_3%	0.03			
Fe_2O_3, %	2.9	3.0		P_2O_5%	0.04	(Colormetric)		
MgO, %	3.6							
SO_3, %	2.6							
LOSS ON IGNITION, %	1.3							
ALKALIES-TOTAL AS Na_2O, %	0.78	Water	Soluble	Alkali	as Na_2O%		0.59	
Na_2O, %	0.12						0.06	
K_2O, %	1.00						0.80	
INSOLUBLE RESIDUE, %	0.13							
CaO, %	63.7							
C_3S, %	61							
C_3A, %	7	6.3						
C_2S, %	13							
$C_3A + C_3S$, %	68							
C_4AF, %	9							
$C_4AF + 2\ C_3A$, %								
HEAT OF HYDRATION, 7D, CAL/G								
HEAT OF HYDRATION, 28D, CAL/G								
SURFACE AREA, SQ CM/G (A.P.I.)	3540							
AIR CONTENT, %	9.5							
COMP. STRENGTH, 3 D, PSI	3010	COMP STR,	90	D, PSI	5320			
COMP. STRENGTH, 7 D, PSI	3880	COMP STR,	180	D, PSI	5610			
COMP. STRENGTH, 28 D, PSI	4800	COMP STR,	365	D, PSI	5560			
FALSE SET—PEN. F.I. %								
SAMPLE NO.	1							
AUTOCLAVE EXP., %	0.09							
INITIAL SET, HR:MIN	3:10							
FINAL SET, HR:MIN	5:10							
SAMPLE NO.								
AUTOCLAVE EXP., %								
INITIAL SET, HR:MIN								
FINAL SET, HR:MIN								

REMARKS

THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U.S. GOVERNMENT

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Group

ENG FORM 1 MAR 73 6008-R

TO	REPORT OF TESTS OF Blended Cement RC-726(2)	FROM CORPS OF ENGINEERS U.S. ARMY Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180

TEST REPORT NO	BIN NO	QNT REPRESENTED	DATE
SPECIFICATION Type 1P		DATE SAMPLED	
COMPANY Missouri Portland	LOCATION Joppa, IL	BRAND	

THIS CEMENT DOES MEET SPECIFICATION REQUIREMENTS

SAMPLE NO	1(WET)	1 (AA)		1(AA)				
SiO_2, %	24.80			TiO_2	0.30			
Al_2O_3, %	8.18	6.15		MN_2O_3	0.03			
Fe_2O_3, %	4.66	4.55		P_2O_5	0.07	Colormetric		
MgO, %	2.84							
SO_3, %	3.03							
LOSS ON IGNITION, %	1.05							
ALKALIES-TOTAL AS Na_2O, %	0.59	Water Soluble Alkali as Na_2O%					0.29	
Na_2O, %	0.13						0.03	
K_2O, %	0.70						0.39	
INSOLUBLE RESIDUE, %								
CaO, %	53.70							
C_3S, %								
C_3A, %								
C_2S, %								
$C_3A + C_3S$, %								
C_4AF, %								
$C_4AF + 2C_3A$, %								
HEAT OF HYDRATION, 7D, CAL/G	69							
HEAT OF HYDRATION, 28D, CAL/G	80							
SURFACE AREA, SQ CM/G (A P)	4050							
AIR CONTENT, %	8.3							
COMP STRENGTH, 3D, PSI	3030	COMP STR, 90 D, PSI			6560			
COMP STRENGTH, 7D, PSI	3780	COMP STR, 180 D, PSI			7825			
COMP STRENGTH, 28D, PSI	4820	COMP STR, 1 YR, PSI			8250			
FALSE SET-PEN F/I, %								
SAMPLE NO.	1							
AUTOCLAVE EXP., %	0.02							
INITIAL SET, HR/MIN	3:35							
FINAL SET, HR/MIN	6:15							
SAMPLE NO.								
AUTOCLAVE EXP., %								
INITIAL SET, HR/MIN								
FINAL SET, HR/MIN								

REMARKS

Density 3.07 Mg/m^3
W/C 0.46
Flow 115%

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

ENG FORM 1 MAR 72 6008-R

PREVIOUS EDITIONS OBSOLETE

TO	REPORT OF TESTS OF PORTLAND CEMENT RC-729	FROM CORPS OF ENGINEERS U. S. ARMY Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Group P.O. Box 631 Vicksburg, MS 39180

TEST REPORT NO	BIN NO	CAT REPRESENTED	DATE
SPECIFICATION Type I		DATE SAMPLED	
COMPANY Santee Cement	LOCATION Holly Hill, SC	BRAND	

THIS CEMENT DOES MEET SPECIFICATION REQUIREMENTS

SAMPLE NO (Analysis)	1(WET)	A)		1(AA)				
SiO_2, %	20.7			TiO_2%	0.27			
Al_2O_3, %	5.5	4.8		Mn_2O_3%	0.01			
Fe_2O_3, %	2.3	2.3		P_2O_5	0.17	(Colormetric)		
MgO, %	1.1							
SO_3, %	2.7							
LOSS ON IGNITION, %	2.1							
ALKALIES-TOTAL AS Na_2O, %	0.34	Water Soluble Alkali as Na_2O%					0.09	
Na_2O, %	0.08						0.01	
K_2O, %	0.40						0.12	
INSOLUBLE RESIDUE, %	0.18							
CaO, %	64.9							
C_3S, %	59							
C_3A, %	11	8.8						
C_2S, %	14							
$C_3A + C_3S$, %	70							
C_4AF, %	7							
$C_4AF + 2\ C_3A$, %								
HEAT OF HYDRATION, 7D, CAL/G								
HEAT OF HYDRATION, 28D, CAL/G								
SURFACE AREA, SQ CM/G (A.P.)	4080							
AIR CONTENT, %	7.3							
COMP STRENGTH 3D, PSI	3350	COMP STR, 90D, PSI			6540			
COMP STRENGTH, 7D, PSI	4770	COMP STR, 180D, PSI			6940			
COMP STRENGTH 28D, PSI	5800	COMP STR, 365D, PSI			6670			
FALSE SET-PEN, F/I								
SAMPLE NO	1							
AUTOCLAVE EXP, %	0.07							
INITIAL SET, HR:MIN	2:25							
FINAL SET, HR:MIN	6:15							
SAMPLE NO								
AUTOCLAVE EXP, %								
INITIAL SET, HR:MIN								
FINAL SET, HR:MIN								

REMARKS

THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U. S. GOVERNMENT

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Group

ENG FORM 1 MAR 72 6008-R

TO	REPORT OF TESTS OF Blended Cement RC-730	FROM CORPS OF ENGINEERS U.S. ARMY Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180

TEST REPORT NO	BIN NO	CWT REPRESENTED	DATE
SPECIFICATION Type 1P		DATE SAMPLED	
COMPANY Santee	LOCATION Holly Hill, S.C.	BRAND	

THIS CEMENT DOES MEET SPECIFICATION REQUIREMENTS

SAMPLE NO	1(WET)	1 (AA)		1(AA)				
SiO_2 %	25.82			TiO_2	0.46			
Al_2O_3 %	10.76	7.75		MN_2O_3	0.01			
Fe_2O_3 %	3.12	2.96		P_2O_5	0.16	(Colormetric)		
MgO %	0.94							
SO_3 %	3.11							
LOSS ON IGNITION, %	1.73							
ALKALIES-TOTAL AS Na_2O %	0.26	Water Soluble Alkali as Na_2O%					0.05	
Na_2O %	0.07						0.01	
K_2O %	0.29						0.06	
INSOLUBLE RESIDUE %								
CaO %	53.55							
C_3S, %								
C_3A, %								
C_2S, %								
$C_3A + C_3S$, %								
C_4AF %								
$C_4AF + 2 C_3A$, %								
HEAT OF HYDRATION 7D, CAL/G	82							
HEAT OF HYDRATION 28D, CAL/G	91							
SURFACE AREA SQ CM/G (A.P.)	4650							
AIR CONTENT %	6.0							
COMP STRENGTH 3 D PSI	3930	COMP STR, 90 D, PSI						
COMP STRENGTH 7 D PSI	4620	COMP STR, 180 D, PSI			8680			
COMP STRENGTH 28 D PSI	5980	COMP STR, 1 YR, PSI			8960			
FALSE SET-PEN								
SAMPLE NO	1							
AUTOCLAVE EXP %	-0.04							
INITIAL SET, HR MIN	3:00							
FINAL SET, HR MIN	6:05							
SAMPLE NO								
AUTOCLAVE EXP %								
INITIAL SET, HR MIN								
FINAL SET, HR/MIN								

REMARKS

Density 2.93 Mg/m^3
W/C 0.486
Flow 112%

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

ENG FORM 1 MAR 73 6008-R

TO	REPORT OF TESTS OF PORTLAND CEMENT RC-731	FROM CORPS OF ENGINEERS U.S. ARMY Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Group P.O. Box 631 Vicksburg, MS 39180

Specification: Type I

Company: Amcord, Phoenix Div — Location: Clarkdale, AZ — Brand:

This cement does — meet specification requirements

Sample No. (Analysis)	1(WET)	1(AA)	1(AA)		
	21.7		TiO_2%	0.27	
	3.7	3.3	Mn_2O_3%	0.03	
	2.5	2.5	P_2O_5%	0.18	(Colormetric)
	4.4				
	2.1				
	2.6				
	0.51	Water Soluble Alkali as Na_2O%			0.09
	0.14				0.01
	0.56				0.12
	0.56				
	64.4				
	63				
	6	5			
	15				
	68				
	8				
	3630				
Air content	7.0				
Comp strength 3	2630	COMP STR, 90D, PSI		5930	
Comp strength 7	3870	COMP STR, 180D, PSI		6120	
Comp strength 28	5050	COMP STR, 365D, PSI		5860	

Sample No.	1
	0.12
	3:40
	6:10

Remarks

W. G.MILLER
Chemist
Chief, Cement & Pozzolan Group

TO	REPORT OF TESTS OF Blended Cement RC-732	FROM CORPS OF ENGINEERS U. S. ARMY Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180

TEST REPORT NO | BIN NO | CWT REPRESENTED | DATE

SPECIFICATION Type IP | DATE SAMPLED

COMPANY Phoenix Div. Amcord | LOCATION Clarkdale, AZ | BRAND

THIS CEMENT DOES MEET SPECIFICATION REQUIREMENTS

SAMPLE NO	1(WET)	1 (AA)		1(AA)				
SiO_2, %	25.62			TiO_2	0.45			
Al_2O_3, %	6.78	5.45		MN_2O_3	0.03			
Fe_2O_3, %	2.82	2.78		P_2O_5	0.02	(Colormetric)		
MgO, %	3.85							
SO_3, %	2.04							
LOSS ON IGNITION, %	1.85							
ALKALIES-TOTAL AS Na_2O, %	0.41	Water	Soluble	Alkali	as Na_2O%		0.08	
Na_2O, %	0.12						0.01	
K_2O, %	0.44						0.10	
INSOLUBLE RESIDUE, %								
CaO, %	55.12							
C_3S, %								
C_3A, %								
C_2S, %								
$C_3A + C_3S$, %								
C_4AF, %								
$C_4AF + 2C_3A$, %								
HEAT OF HYDRATION, 7D, CAL/G	71							
HEAT OF HYDRATION, 28D, CAL/G	81							
SURFACE AREA, SQ CM/G (A.P.)	4080							
AIR CONTENT, %	5.6							
COMP STRENGTH, 3 D, PSI	3110	COMP STR, 90	D, PSI		6360			
COMP STRENGTH, 7 D, PSI	3640	COMP STR, 180	D, PSI		7210			
COMP STRENGTH, 28 D, PSI	4780	COMP STR, 1 YR,	PSI		7820			
FALSE SET-PEN, F.I., %								
SAMPLE NO.	1							
AUTOCLAVE EXP., %	0.10							
INITIAL SET, HR:MIN	3:35							
FINAL SET, HR:MIN	5:40							
SAMPLE NO								
AUTOCLAVE EXP., %								
INITIAL SET, HR:MIN								
FINAL SET, HR:MIN								

REMARKS

Density 2.98 Mg/m^3
W/C 0.486
Flow 14%

THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U. S. GOVERNMENT

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

ENG FORM 1 MAR 72 6008-R

TO	REPORT OF TESTS OF PORTLAND CEMENT RC-733	FROM CORPS OF ENGINEERS Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Group P.O. Box 631 Vicksburg, MS 39180

TEST REPORT NO	BIN NO	QTY REPRESENTED	DATE
SPECIFICATION Type I		DATE SAMPLED	
COMPANY Medusa	LOCATION Clinchfield, GA	BRAND	
THIS CEMENT DOES MEET SPECIFICATION REQUIREMENTS			

SAMPLE NO (Analysis)	1(WET)	1(AA)		1(AA)				
SiO_2 %	21.9			TiO_2%	0.30			
Al_2O_3 %	4.7	4.3		Mn_2O_3%	0.08			
Fe_2O_3 %	2.2	2.2		P_2O_5%	0.08	(Colormetric)		
MgO %	0.7							
SO_3 %	2.7							
LOSS ON IGNITION %	2.3							
ALKALIES-TOTAL AS Na_2O %	0.25	Water	Soluble	Alkali as Na_2O%			0.02	
Na_2O %	0.03						0.00	
K_2O %	0.33						0.03	
INSOLUBLE RESIDUE %	0.19							
CaO %	65.4							
C_3S %	57							
C_3A %	9	8						
C_2S %	20							
$C_3A + C_3S$ %	66							
C_4AF %	7							
$C_4AF + 2\ C_3A$ %								
HEAT OF HYDRATION 7D, CAL/G								
HEAT OF HYDRATION 28D, CAL/G								
SURFACE AREA SQ CM/G AIR	3870							
AIR CONTENT %	9.6							
COMP STRENGTH 3 D PSI	2830	COMP STR, 90D, PSI			6560			
COMP STRENGTH 7 D PSI	4310	COMP STR, 180D, PSI			7190			
COMP STRENGTH 28 D PSI	5860	COMP STR, 365D, PSI			7170			
FALSE SET-PEN								
SAMPLE NO	1							
AUTOCLAVE EXP	0.03							
INITIAL SET, HR MIN	3:30							
FINAL SET, HR MIN	5:55							
SAMPLE NO								
AUTOCLAVE EXP								
INITIAL SET, HR MIN								
FINAL SET, HR MIN								

REMARKS

THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U.S. GOVERNMENT

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Group

ENG FORM 1 MAR 72 5008-R

TO	REPORT OF TESTS OF PORTLAND CEMENT RC-734	FROM CORPS OF ENGINEERS, U.S. ARMY Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Group P.O. Box 631 Vicksburg, MS 39180

TEST REPORT NO	P.O. NO	WT REPRESENTED	DATE
SPECIFICATION Type I		DATE SAMPLED	
COMPANY Dundee Cement	LOCATION Dundee, MI		BRAND
THIS CEMENT DOES	MEET SPECIFICATION REQUIREMENTS		

SAMPLE NO (Analysis)	1(WET)	1(AA)		1(AA)				
SiO_2, %	20.3			TiO_2%	0.25			
Al_2O_3, %	5.4	5.0		Mn_2O_3%	0.03			
Fe_2O_3, %	2.9	3.0		P_2O_5%	0.06	(Colormetric)		
MgO, %	2.8							
SO_3, %	2.6							
LOSS ON IGNITION, %	1.3							
ALKALIES-TOTAL AS Na_2O, %	0.70	Water	Soluble	Alkali as Na_2O%			0.22	
Na_2O, %	0.28						0.04	
K_2O, %	0.64						0.28	
INSOLUBLE RESIDUE, %	0.28							
CaO, %	63.7							
C_3S, %	55							
C_3A, %	9	8						
C_2S, %	16							
$C_3A + C_3S$, %	65							
C_4AF, %	9							
$C_4AF + 2C_3A$, %								
HEAT OF HYDRATION, 7D, CAL/G								
HEAT OF HYDRATION, 28D, CAL/G								
SURFACE AREA, SQ CM/G (A.P.)	3450							
AIR CONTENT, %	9.7							
COMP. STRENGTH, 3D, PSI	2800	COMP STR,	90D	PSI	5270			
COMP. STRENGTH, 7D, PSI	4260	COMP STR,	180D	PSI	5680			
COMP. STRENGTH, 28D, PSI	5100	COMP STR,	365D	PSI	5370			
FALSE SET-PEN. FIN., %								
SAMPLE NO	1							
AUTOCLAVE EXP., %	0.05							
INITIAL SET, HR/MIN	2:55							
FINAL SET, HR/MIN	5:00							
SAMPLE NO								
AUTOCLAVE EXP., %								
INITIAL SET, HR/MIN								
FINAL SET, HR/MIN								

REMARKS

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Group

ENG FORM 6008-R
1 MAR 72

TO	REPORT OF TESTS OF Blended Cement RC-735	FROM CORPS OF ENGINEERS U. S. ARMY Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180

TEST REPORT NO	BIN NO	LOT REPRESENTED	DATE
SPECIFICATION Type 1P		DATE SAMPLED	
COMPANY Dundee	LOCATION Dundee, MI		BRAND

THIS CEMENT DOES MEET SPECIFICATION REQUIREMENTS

SAMPLE NO	1(WET)	1 (AA)		1(AA)				
SiO_2, %	25.96			TiO_2	0.44			
Al_2O_3, %	10.26	8.02		MN_2O_3	0.04			
Fe_2O_3, %	4.64	4.41		P_2O_5	0.06	(Colormetric)		
MgO, %	2.27							
SO_3, %	2.34							
LOSS ON IGNITION, %	2.22							
ALKALIES-TOTAL AS Na_2O, %	0.53	Water Soluble		Alkali as Na_2O%			0.16	
Na_2O, %	0.21						0.04	
K_2O, %	0.49						0.20	
INSOLUBLE RESIDUE, %								
CaO, %	50.94							
C_3S, %								
C_3A, %								
C_2S, %								
$C_3A + C_3S$, %								
C_4AF, %								
$C_4AF + 2C_3A$, %								
HEAT OF HYDRATION, 7D, CAL/G	75							
HEAT OF HYDRATION, 28D, CAL/G	83							
SURFACE AREA, SQ CM/G (A.P.)	3800							
AIR CONTENT, %	5.7							
COMP. STRENGTH, 3D, PSI	2840	COMP STR, 90 D, PSI			5950			
COMP. STRENGTH, 7D, PSI	3620	COMP STR, 180 D, PSI			6850			
COMP. STRENGTH, 28D, PSI	4620	COMP STR, 1 YR, PSI			6990			
FALSE SET-PEN. F.I., %								
SAMPLE NO.	1							
AUTOCLAVE EXP., %	0.00							
INITIAL SET, HR:MIN	3:20							
FINAL SET, HR:MIN	6:10							
SAMPLE NO.								
AUTOCLAVE EXP., %								
INITIAL SET, HR:MIN								
FINAL SET, HR:MIN								

REMARKS

Density 2.95 Mg/m^3
W/C 0.486
Flow 111%

THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U. S. GOVERNMENT

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

ENG FORM 1 MAR 72 6008-R

TO	REPORT OF TESTS OF PORTLAND CEMENT RC-736	FROM CORPS OF ENGINEERS U.S. ARMY Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Group P.O. Box 631 Vicksburg, MS 39180

TEST REPORT NO. | BIN NO. | AMT REPRESENTED | DATE

SPECIFICATION Type I, II | DATE SAMPLED

COMPANY Lone Star | LOCATION Sweetwater, TX | BRAND

THIS CEMENT DOES MEET SPECIFICATION REQUIREMENTS

SAMPLE NO. (Analysis)	1(WET)	1(AA)		1(AA)				
SiO_2, %	21.6			TiO_2%	0.19			
Al_2O_3, %	4.0	3.8		Mn_2O_3%	0.01			
Fe_2O_3, %	3.2	3.1		P_2O_5%	0.04	(Colormetric)		
MgO, %	2.0							
SO_3, %	2.2							
LOSS ON IGNITION, %	1.2							
ALKALIES-TOTAL AS Na_2O, %	0.65	Water Soluble		Alkali	as Na_2O%		0.36	
Na_2O, %	0.16						0.04	
K_2O, %	0.75						0.49	
INSOLUBLE RESIDUE, %	1.20							
CaO, %	64.8							
C_3S, %	62							
C_3A, %	5	5						
C_2S, %	15							
$C_3A + C_3S$, %	67							
C_4AF, %	10							
$C_4AF + 2C_3A$, %	20							
HEAT OF HYDRATION, 7D, CAL/G								
HEAT OF HYDRATION, 28D, CAL/G								
SURFACE AREA, SQ CM/G (A.P.)	3480							
AIR CONTENT, %	9.8							
COMP. STRENGTH, 3 D, PSI	2860	COMP STR, 90D, PSI			5070			
COMP. STRENGTH, 7 D, PSI	3570	COMP STR, 180D, PSI			5520			
COMP. STRENGTH 28 D, PSI	4540	COMP STR, 365D, PSI			5400			
FALSE SET-PEN, F.I. %								
SAMPLE NO.	1							
AUTOCLAVE EXP., %	0.01							
INITIAL SET, HR:MIN	3:15							
FINAL SET, HR:MIN	4:50							
SAMPLE NO.								
AUTOCLAVE EXP., %								
INITIAL SET, HR:MIN								
FINAL SET, HR:MIN								

REMARKS

THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U. S. GOVERNMENT

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Group

ENG FORM 6008-R
1 MAR 72

TO.	REPORT OF TESTS OF PORTLAND CEMENT RC-737	FROM CORPS OF ENGINEERS U. S. ARMY Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Group P.O. Box 631 Vicksburg, MS 39180

TEST REPORT NO | BIN NO | CWT REPRESENTED | DATE

SPECIFICATION Type III | DATE SAMPLED

COMPANY Lone Star | LOCATION Sweetwater, TX | BRAND

THIS CEMENT DOES MEET SPECIFICATION REQUIREMENTS

SAMPLE NO.	1WET	IAA		IAA				
SiO_2, %	20.9			TiO_2	0.14			
Al_2O_3, %	2.8	2.4		MN_2O_3	0.01			
Fe_2O_3, %	4.9	4.9		P_2O_5	0.06	(Colormetric)		
MgO, %	1.6							
SO_3, %	3.4							
LOSS ON IGNITION, %	1.4							
ALKALIES-TOTAL AS Na_2O, %	0.41	Water Soluble Alkalies as Na_2O					0.21	
Na_2O, %	0.11						0.02	
K_2O, %	0.46						0.29	
INSOLUBLE RESIDUE, %	0.14							
CaO, %	64.4							
C_3S, %	67							
C_3A, %	NONE							
C_2S, %	10							
$C_3A + C_3S$, %	NONE							
C_4AF, %	NONE							
$C_4AF + C_2F)ss$	14	13						
HEAT OF HYDRATION, 7D, CAL G								
HEAT OF HYDRATION, 28D, CAL G								
SURFACE AREA, SQ CM G (A.P.)	4850							
AIR CONTENT, %	10.2							
COMP. STRENGTH, 3 D, PSI	3930	COMP STR. 90D PSI			6320			
COMP. STRENGTH, 7 D, PSI	5000	COMP STR. 180D PSI			6920			
COMP. STRENGTH, 28 D, PSI	5900	COMP STR. 365D PSI			6980			
FALSE SET-PEN. F.1, %								
SAMPLE NO.								
AUTOCLAVE EXP., %	-0.04							
INITIAL SET, HR/MIN	3:25							
FINAL SET, HR/MIN	6:10							
SAMPLE NO.								
AUTOCLAVE EXP., %								
INITIAL SET, HR/MIN								
FINAL SET, HR/MIN								

REMARKS

THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U. S. GOVERNMENT

ENG FORM 1 MAR 72 6008-R

TO:	REPORT OF TESTS OF PORTLAND CEMENT RC-738	FROM: U.S. ARMY CORPS OF ENGINEERS Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Group P.O. Box 631 Vicksburg, MS 39180

TEST REPORT NO	BIN NO	AMT REPRESENTED	DATE
SPECIFICATION Type I		DATE SAMPLED	
COMPANY Dundee Portland Co.	LOCATION Clarksville, MO		BRAND
THIS CEMENT DOES	MEET SPECIFICATION REQUIREMENTS		

SAMPLE NO (Analysis)	1(WET)		1(AA)		1(AA)			
SiO_2, %	20.1				TiO_2	0.24		
Al_2O_3, %	5.6		5.0		Mn_2O_3	0.05		
Fe_2O_3, %	2.3		2.3		P_2O_5	0.19	(Colormetric)	
MgO, %	3.4							
SO_3, %	2.7							
LOSS ON IGNITION, %	2.3							
ALKALIES-TOTAL AS Na_2O, %	0.56	Water Soluble Alkali as Na_2O					0.24	
Na_2O, %	0.10						0.02	
K_2O, %	0.70						0.34	
INSOLUBLE RESIDUE, %	0.17							
CaO, %	62.5							
C_3S, %	53							
C_3A, %	11		9.3					
C_2S, %	17							
$C_3A + C_3S$, %	64							
C_4AF, %	7							
$C_4AF + 2C_3A$, %								
HEAT OF HYDRATION, 7D, CAL/G								
HEAT OF HYDRATION, 28D, CAL/G								
SURFACE AREA, SQ CM/G (A.P.)	3800							
AIR CONTENT, %	10.4							
COMP. STRENGTH, 3D, PSI	2600	COMP STR, 90D PSI			5460			
COMP. STRENGTH, 7D, PSI	3680	COMP STR, 180D PSI			5760			
COMP. STRENGTH, 28D, PSI	4900	COMP STR, 365D PSI			5600			
FALSE SET-PEN. F.I., %								
SAMPLE NO.	1							
AUTOCLAVE EXP., %	0.14							
INITIAL SET, HR/MIN	3:35							
FINAL SET, HR/MIN	4:55							
SAMPLE NO.								
AUTOCLAVE EXP., %								
INITIAL SET, HR/MIN								
FINAL SET, HR/MIN								

REMARKS:

ENG FORM 1 MAR 72 6008-R

TO	REPORT OF TESTS OF Blended Cement RC-739	FROM CORPS OF ENGINEERS U. S. ARMY Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180

TEST REPORT NO	BIN NO	CWT REPRESENTED	DATE
SPECIFICATION Type IP		DATE SAMPLED	
COMPANY Dundee	LOCATION Clarksville, MO	BRAND	
THIS CEMENT DOES MEET SPECIFICATION REQUIREMENTS			

SAMPLE NO.	1(WET)	1(AA)		1(AA)				
SiO_2, %	25.40			TiO_2	0.39			
Al_2O_3, %	8.11	6.83		MN_2O_3	0.05			
Fe_2O_3, %	5.00	4.76		P_2O_5	0.16	Colormetric		
MgO, %	2.73							
SO_3, %	1.81							
LOSS ON IGNITION, %	2.56							
ALKALIES-TOTAL AS Na_2O, %	0.49	Water Soluble Alkali as Na_2O%				0.21		
Na_2O, %	0.11					0.02		
K_2O, %	0.58					0.28		
INSOLUBLE RESIDUE, %								
CaO, %	52.30							
C_3S, %								
C_3A, %								
C_2S, %								
$C_3A + C_3S$, %								
C_4AF, %								
$C_4AF + 2C_3A$, %								
HEAT OF HYDRATION, 7D, CAL/G	70							
HEAT OF HYDRATION, 28D, CAL/G	77							
SURFACE AREA, SQ CM/G (A.P.)	3950							
AIR CONTENT, %	7.3							
COMP. STRENGTH, 3D, PSI	2940	COMP STR, 90 D, PSI			6260			
COMP. STRENGTH, 7D, PSI	3840	COMP STR, 180 D, PSI			7910			
COMP. STRENGTH, 28D, PSI	5130	COMP STR, 1 YR, PSI			7970			
FALSE SET-PEN. F. I., %								
SAMPLE NO.	1							
AUTOCLAVE EXP., %	-0.04							
INITIAL SET, HR/MIN	3:35							
FINAL SET, HR/MIN	5:45							
SAMPLE NO.								
AUTOCLAVE EXP., %								
INITIAL SET, HR/MIN								
FINAL SET, HR/MIN								

REMARKS:

Density 3.00 Mg/m^3
W/C 0.476
Flow 113%

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

ENG FORM 6008-R
1 MAR 72

TO:	REPORT OF TESTS OF Blended Cement RC-740	FROM CORPS OF ENGINEERS U. S. ARMY Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180

TEST REPORT NO. | BIN NO. | CWT REPRESENTED: | DATE:

SPECIFICATION Type 1-P (bottom ash) | DATE SAMPLED:

COMPANY Dundee | LOCATION Clarksville, MO | BRAND

THIS CEMENT DOES MEET SPECIFICATION REQUIREMENTS

SAMPLE NO.	1(WET)	1 (AA)		1(AA)				
SiO_2, %	23.67			TiO_2	0.33			
Al_2O_3, %	7.57	6.06		MN_2O_3	0.05			
Fe_2O_3, %	3.75	3.68		P_2O_5	0.16	(Colormetric)		
MgO, %	3.24							
SO_3, %	2.27							
LOSS ON IGNITION, %	1.51							
ALKALIES-TOTAL AS Na_2O, %	0.57	Water Soluble Alkali as Na_2O%					0.22	
Na_2O, %	0.08						0.02	
K_2O, %	0.60						0.32	
INSOLUBLE RESIDUE, %								
CaO, %	56.27							
C_3S, %								
C_3A, %								
C_2S, %								
$C_3A + C_3S$, %								
C_4AF, %								
$C_4AF + 2C_3A$, %								
HEAT OF HYDRATION, 7D, CAL/G	74							
HEAT OF HYDRATION, 28D, CAL/G	81							
SURFACE AREA, SQ CM/G (A.P.)	3910							
AIR CONTENT, %	8.7							
COMP. STRENGTH, 3 D, PSI	2820	COMP STR, 90 D, PSI			5680			
COMP. STRENGTH, 7 D, PSI	3510	COMP STR, 180 D, PSI			6620			
COMP. STRENGTH, 28 D, PSI	4800	COMP STR, 1 YR, PSI			7100			
FALSE SET-PEN. F. I., %								
SAMPLE NO.	1							
AUTOCLAVE EXP., %	0.06							
INITIAL SET, HR/MIN	3:35							
FINAL SET, HR/MIN	5:45							
SAMPLE NO.								
AUTOCLAVE EXP., %								
INITIAL SET, HR/MIN								
FINAL SET, HR/MIN								

REMARKS:

Density 3.05 Mg/m^3
W/C 0.484
Flow 114%

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

ENG FORM 1 MAR 78 6008-R

TO	REPORT OF TESTS OF PORTLAND CEMENT RC-741	FROM CORPS OF ENGINEERS U. S. ARMY Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180

TEST REPORT NO	BIN NO	CWT REPRESENTED	DATE
SPECIFICATION Type I		DATE SAMPLED	
COMPANY Penn-Dixie	LOCATION Kingsport, TN		BRAND

THIS CEMENT DOES MEET SPECIFICATION REQUIREMENTS

SAMPLE NO (Analysis)	1(WET)	1 (AA)			1 (AA)			
SiO_2, %	22.0				TiO_2%	0.22		
Al_2O_3, %	5.4	4.7			Mn_2O_3	0.04		
Fe_2O_3, %	2.4	2.4			P_2O_5	0.14	(Colormetric)	
MgO, %	1.5							
SO_3, %	2.2							
LOSS ON IGNITION, %	1.3							
ALKALIES-TOTAL AS Na_2O, %	0.32	Water	Soluble	Alkali	as Na_2O%		0.10	
Na_2O, %	0.13						0.02	
K_2O, %	0.29						0.13	
INSOLUBLE RESIDUE, %	0.34							
CaO, %	64.9							
C_3S, %	51							
C_3A, %	10	8.5						
C_2S, %	25							
$C_3A + C_3S$, %	61							
C_4AF, %	7							
$C_4AF + 2C_3A$, %								
HEAT OF HYDRATION, 7D, CAL/G								
HEAT OF HYDRATION, 28D, CAL/G								
SURFACE AREA, SQ CM/G (A.P.)	3620							
AIR CONTENT, %	9.1							
COMP. STRENGTH, 3 D, PSI	2590	COMP STR, 90 D, PSI			6980			
COMP. STRENGTH, 7 D, PSI	4400	COMP STR, 180 D, PSI			7300			
COMP. STRENGTH, 28 D, PSI	5960	COMP STR, 365 D, PSI			7300			
FALSE SET-PEN. F. I., %								
SAMPLE NO.	1							
AUTOCLAVE EXP., %	0.03							
INITIAL SET, HR/MIN	2:45							
FINAL SET, HR/MIN	5:15							
SAMPLE NO.								
AUTOCLAVE EXP., %								
INITIAL SET, HR/MIN								
FINAL SET, HR/MIN								

REMARKS

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

ENG FORM 1 MAR 72 6008-R

TO:	REPORT OF TESTS OF Blended Cement RC-742	FROM CORPS OF ENGINEERS U. S. ARMY Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180

TEST REPORT NO	BIN NO	CWT REPRESENTED	DATE
SPECIFICATION Type 1P		DATE SAMPLED	
COMPANY Penn-Dixie	LOCATION Kingsport, TN	BRAND	

THIS CEMENT DOES MEET SPECIFICATION REQUIREMENTS

SAMPLE NO	1(WET)	1 (AA)		1(AA)				
SiO_2, %	25.27			TiO_2	0.37			
Al_2O_3, %	9.73	7.39		MN_2O_3	0.04			
Fe_2O_3, %	3.04	2.93		P_2O_5	0.12			
MgO, %	1.81							
SO_3, %	2.77							
LOSS ON IGNITION, %	1.71							
ALKALIES-TOTAL AS Na_2O, %	0.34	Water	Soluble	Alkali	as Na_2O%		0.10	
Na_2O, %	0.12						0.02	
K_2O, %	0.34						0.13	
INSOLUBLE RESIDUE, %								
CaO, %	54.29							
C_3S, %								
C_3A, %								
C_2S, %								
$C_3A + C_3S$, %								
C_4AF, %								
$C_4AF + 2\ C_3A$, %								
HEAT OF HYDRATION, 7D, CAL/G	76							
HEAT OF HYDRATION, 28D, CAL/G	87							
SURFACE AREA, SQ CM/G (A.P.)	4140							
AIR CONTENT, %	5.2							
COMP. STRENGTH, 3D, PSI	3300	COMP	STR, 90	D, PSI	6780			
COMP. STRENGTH, 7D, PSI	4190	COMP	STR, 180	D, PSI	8860			
COMP. STRENGTH, 28D, PSI	5740	COMP	STR, 1 YR	, PSI	8620			
FALSE SET-PEN. F. I. %								
SAMPLE NO.	1							
AUTOCLAVE EXP., %	0.00							
INITIAL SET, HR/MIN	3:05							
FINAL SET, HR/MIN	5:10							
SAMPLE NO.								
AUTOCLAVE EXP., %								
INITIAL SET, HR/MIN								
FINAL SET, HR/MIN								

REMARKS:

Density 2.97 Mg/m^3
W/C 0.484
Flow 114%

THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U. S. GOVERNMENT

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

ENG FORM 1 MAR 72 6008-R

TO	REPORT OF TESTS OF PORTLAND CEMENT RC-744	FROM CORPS OF ENGINEERS U.S. ARMY Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Group P.O. Box 631 Vicksburg, MS 39180

TEST REPORT NO | BIN NO | CWT REPRESENTED | DATE

SPECIFICATION Type I | DATE SAMPLED

COMPANY Texas Industries | LOCATION Midlothian, TX | BRAND

THIS CEMENT DOES MEET SPECIFICATION REQUIREMENTS

SAMPLE NO (Analysis)	1(WET)		1(AA)		1(AA)			
SiO_2, %	21.2				TiO_2	0.21		
Al_2O_3, %	5.5		4.9		Mn_2O_2	0.26		
Fe_2O_3, %	3.0		2.9		P_2O_5	0.18	(Colorimetric)	
MgO, %	0.6							
SO_3, %	2.5							
LOSS ON IGNITION, %	1.8							
ALKALIES-TOTAL AS Na_2O, %	0.38	Water Soluble Alkali as Na_2O%					0.13	
Na_2O, %	0.12						0.02	
K_2O, %	0.40						0.17	
INSOLUBLE RESIDUE, %	0.27							
CaO, %	64.4							
C_3S, %	53							
C_3A, %	9		8.1					
C_2S, %	20							
$C_3A + C_3S$, %	63							
C_4AF, %	9							
$C_4AF + 2 C_3A$, %								
HEAT OF HYDRATION, 7D, CAL/G								
HEAT OF HYDRATION, 28D, CAL/G								
SURFACE AREA, SQ CM/G (A.P.)	3150							
AIR CONTENT, %	9.5							
COMP. STRENGTH, 3D, PSI	2340	COMP STR, 90D, PSI			5810			
COMP. STRENGTH, 7D, PSI	3230	COMP STR, 180D, PSI			6280			
COMP. STRENGTH, 28D, PSI	4780	COMP STR, 365D, PSI			6150			
FALSE SET-PEN. F.I. %								
SAMPLE NO.	1							
AUTOCLAVE EXP., %	0.02							
INITIAL SET, HR/MIN	3:00							
FINAL SET, HR/MIN	5:25							
SAMPLE NO								
AUTOCLAVE EXP., %								
INITIAL SET, HR/MIN								
FINAL SET, HR/MIN								

REMARKS

THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U.S. GOVERNMENT

ENG FORM 1 MAR 72 6008-R

TO	REPORT OF TESTS OF Blended Cement RC-745	FROM CORPS OF ENGINEERS U.S. ARMY Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180

TEST REPORT NO.		QUANTITY REPRESENTED	DATE
SPECIFICATION Type IP		DATE SAMPLED	
COMPANY Texas Industries	LOCATION Midlothian, TX	BRAND	
THIS CEMENT DOES	MEET SPECIFICATION REQUIREMENTS		

SAMPLE NO.	1(WET)	1 (AA)		1(AA)				
SiO_2, %	29.23			TiO_2	0.42			
Al_2O_3, %	9.33	6.78		MN_2O_3	0.22			
Fe_2O_3, %	3.08	2.96		P_2O_5	0.16	(Colormetric)		
MgO, %	0.82							
SO_3, %	2.05							
LOSS ON IGNITION, %	1.24							
ALKALIES-TOTAL AS Na_2O, %	0.32	Water Soluble Alkali as Na_2O%					0.10	
Na_2O, %	0.11						0.02	
K_2O, %	0.32						0.13	
INSOLUBLE RESIDUE, %								
CaO, %	53.19							
C_3S, %								
C_3A, %								
C_2S, %								
$C_3A + C_3S$, %								
C_4AF, %								
$C_4AF + 2C_3A$, %								
HEAT OF HYDRATION, 7D, CAL/G	65							
HEAT OF HYDRATION, 28D, CAL/G	78							
SURFACE AREA, SQ CM/G (A.P.)	3650							
AIR CONTENT, %	8.2							
COMP. STRENGTH, 3D, PSI	2160	COMP STR, 90 D, PSI			7500			
COMP. STRENGTH, 7D, PSI	3340	COMP STR, 180 D, PSI			9220			
COMP. STRENGTH, 28D, PSI	4890	COMP STR, 1 YR, PSI			9460			
FALSE SET-PEN., FINAL								
SAMPLE NO.	1							
AUTOCLAVE EXP., %	0.00							
INITIAL SET, HR/MIN	4:10							
FINAL SET, HR/MIN	6:40							
SAMPLE NO.								
AUTOCLAVE EXP., %								
INITIAL SET, HR/MIN								
FINAL SET, HR/MIN								

REMARKS

Density 2.96 Mg/m^3
W/C 0.450
Flow 112%

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

ENG FORM 1 MAR 72 6008-R

TO	REPORT OF TESTS OF PORTLAND CEMENT RC-746	FROM CORPS OF ENGINEERS U.S. ARMY Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180

TEST REPORT NO	BIN NO	AMT REPRESENTED	DATE
SPECIFICATION Type I		DATE SAMPLED	
COMPANY Southwestern	LOCATION Fairborn, OH	BRAND	
THIS CEMENT DOES	MEET SPECIFICATION REQUIREMENTS		

SAMPLE NO (Analysis)	1(WET)	1 (AA)			1 (AA)			
SiO_2, %	20.8				TiO_2%	0.22		
Al_2O_3, %	4.9	4.5			Mn_2O_3	0.05		
Fe_2O_3, %	2.9	2.9			P_2O_5	0.07	(Colormetric)	
MgO, %	4.3							
SO_3, %	2.4							
LOSS ON IGNITION, %	2.4							
ALKALIES-TOTAL AS Na_2O, %	0.75	Water Soluble Alkali as Na_2O%					0.38	
Na_2O, %	0.22						0.06	
K_2O, %	0.80						0.49	
INSOLUBLE RESIDUE, %	0.34							
CaO, %	62							
C_3S, %	50							
C_3A, %	8	7.0						
C_2S, %	22							
$C_3A + C_3S$, %	58							
C_4AF, %	9							
$C_4AF + 2\,C_3A$, %								
HEAT OF HYDRATION, 7D, CAL/G								
HEAT OF HYDRATION, 28D, CAL/G								
SURFACE AREA, SQ CM/G (A.P.)	3770							
AIR CONTENT, %	10.0							
COMP STRENGTH 3 D, PSI	2760	COMP STR. 90 D PSI			5190			
COMP STRENGTH 7 D, PSI	3140	COMP STR. 180 D PSI			5590			
COMP STRENGTH 28 D, PSI	4710	COMP STR. 365 D PSI			5640			
FALSE SET-PEN, F, %								
SAMPLE NO	1							
AUTOCLAVE EXP, %	0.14							
INITIAL SET, HR/MIN	3:00							
FINAL SET, HR/MIN	4:55							
SAMPLE NO								
AUTOCLAVE EXP, %								
INITIAL SET, HR/MIN								
FINAL SET, HR/MIN								

REMARKS

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

ENG FORM 1 MAR 72 6008-R

TO	REPORT OF TESTS OF PORTLAND CEMENT RC-751	FROM CORPS OF ENGINEERS U.S. ARMY Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180

TEST REPORT NO | BIN NO. | CWT REPRESENTED | DATE

SPECIFICATION: Type I | DATE SAMPLED

COMPANY: Universal Atlas | LOCATION: Leeds, AL | BRAND

THIS CEMENT DOES MEET SPECIFICATION REQUIREMENTS

SAMPLE NO. Analysis)	1(WET)	1 (AA)			1 (AA)			
SiO_2, %	20.8				TiO_2%	0.24		
Al_2O_3, %	5.6	5.0			Mn_2O_3	0.03		
Fe_2O_3, %	2.5	2.4			P_2O_5	0.04	(Colormetric)	
MgO, %	2.8							
SO_3, %	2.5							
LOSS ON IGNITION, %	1.6							
ALKALIES - TOTAL AS Na_2O, %	0.40	Water Soluble Alkali as Na_2O%					0.11	
Na_2O, %	0.14						0.02	
K_2O, %	0.40						0.13	
INSOLUBLE RESIDUE, %	0.22							
CaO, %	64							
C_3S, %	55							
C_3A, %	11	9.3						
C_2S, %	18							
$C_3A + C_3S$, %	65							
C_4AF, %	8							
$C_4AF + 2 C_3A$, %								
HEAT OF HYDRATION, 7D, CAL/G								
HEAT OF HYDRATION, 28D, CAL/G								
SURFACE AREA, SQ CM/G (A.P.)	4050							
AIR CONTENT, %	9.5							
COMP STRENGTH, 3 D, PSI	2950	COMP STR, 90 D PSI			5920			
COMP STRENGTH, 7 D, PSI	4220	COMP STR, 180 D PSI			6360			
COMP STRENGTH 28 D, PSI	5680	COMP STR, 365 D PSI			6440			
FALSE SET - PEN. F/I, %								
SAMPLE NO.	1							
AUTOCLAVE EXP., %	0.33							
INITIAL SET, HR/MIN	3:00							
FINAL SET, HR/MIN	5:00							
SAMPLE NO.								
AUTOCLAVE EXP., %								
INITIAL SET, HR MIN								
FINAL SET, HR/MIN								

REMARKS:

THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U.S. GOVERNMENT

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

TO	REPORT OF TESTS OF Blended Cement RC-752	FROM: CORPS OF ENGINEERS U.S. ARMY Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180

SPECIFICATION: Type IS

COMPANY: Universal Atlas — Leeds, AL

THIS CEMENT DOES MEET SPECIFICATION REQUIREMENTS

SAMPLE NO.	1(WET)	1 (AA)	1(AA)			
SiO_2, %	22.99		TiO_2	0.24		
Al_2O_3, %	5.86	4.85	MN_2O_3	0.03		
Fe_2O_3, %	2.06	2.33	P_2O_5	0.16 (Colormetric)		
MgO, %	1.98					
SO_3	2.95					
LOSS ON IGNITION, %	1.96					
ALKALIES-TOTAL AS Na_2O, %	0.43	Water Soluble Alkali as Na_2O%			0.04	
Na_2O, %	0.17				0.02	
K_2O, %	0.40				0.03	
INSOLUBLE RESIDUE, %						
CaO, %	61.34					
C_3S, %						
C_3A, %						
C_2S, %						
$C_3A + C_3S$, %						
C_4AF, %						
$C_4AF + 2C_3A$, %						
HEAT OF HYDRATION, 7D, CAL/G	80					
HEAT OF HYDRATION, 28D, CAL/G	86					
SURFACE AREA, SQ CM/G, A.P.	4470					
AIR CONTENT, %	9.4					
COMP STRENGTH, 3 D, PSI	3260	COMP STR, 90 D, PSI		6930		
COMP STRENGTH, 7 D, PSI	4560	COMP STR, 180 D, PSI		8470		
COMP STRENGTH, 28 D, PSI	5520	COMP STR, 1 YR, PSI		9080		
FALSE SET, PEN						
SAMPLE NO.	1					
AUTOCLAVE EXP., %	0.12					
INITIAL SET, HR:MIN	3:45					
FINAL SET, HR:MIN	6:10					
SAMPLE NO.						
AUTOCLAVE EXP., %						
INITIAL SET, HR:MIN						
FINAL SET, HR:MIN						

REMARKS

Density 3.07 Mg/m^3
W/C 0.485
Flow 111%

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

ENG FORM 1 MAR 72 6008-R

TO	REPORT OF TESTS OF PORTLAND CEMENT RC-753	FROM CORPS OF ENGINEERS U. S. ARMY Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180

TEST REPORT NO	B/L NO	CWT REPRESENTED	DATE

SPECIFICATION Type II — DATE SAMPLED

COMPANY Ideal — LOCATION Fort Collins, CO — BRAND

THIS CEMENT DOES MEET SPECIFICATION REQUIREMENTS

SAMPLE NO (Analysis)	1(WET)	1 (AA)			1 (AA)			
SiO_2, %	21.4				TiO_2%	0.15		
Al_2O_3, %	4.0	3.5			Mn_2O_3	0.20		
Fe_2O_3, %	3.9	3.7			P_2O_5	0.09	(Colormetric)	
MgO, %	1.4							
SO_3, %	2.5							
LOSS ON IGNITION, %	1.9							
ALKALIES-TOTAL AS Na_2O, %	0.63	Water Soluble Alkali as Na_2O%					0.35	
Na_2O %	0.20						0.06	
K_2O %	0.66						0.44	
INSOLUBLE RESIDUE, %	0.19							
CaO %	63.7							
C_3S, %	57							
C_3A, %	4	3.0						
C_2S, %	18							
$C_3A + C_3S$ %	61							
C_4AF, %	12							
$C_4AF + 2C_3A$, %								
HEAT OF HYDRATION, 7D, CAL G								
HEAT OF HYDRATION, 28D, CAL G								
SURFACE AREA, SQ CM G (A.P.)	3850							
AIR CONTENT, %	10.0							
COMP. STRENGTH, 3 D, PSI	3120	COMP STR, 90 D PSI			5930			
COMP. STRENGTH, 7 D, PSI	4130	COMP STR, 180		D PSI	6380			
COMP. STRENGTH, 28 D, PSI	5390	COMP STR, 365 D PSI			6620			
FALSE SET-PEN. F. I.								
SAMPLE NO.	1							
AUTOCLAVE EXP., %	-0.04							
INITIAL SET, HR/MIN	4:00							
FINAL SET, HR/MIN	6:30							
SAMPLE NO								
AUTOCLAVE EXP., %								
INITIAL SET, HR/MIN								
FINAL SET, HR/MIN								

REMARKS

THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U. S. GOVERNMENT

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

ENG FORM 6008-R
1 MAR 72

TO	REPORT OF TESTS OF PORTLAND CEMENT RC-754	FROM CORPS OF ENGINEERS, U.S. ARMY Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180

TEST REPORT NO.	SERIAL NO.	DATE RECEIVED	DATE
SPECIFICATION SS-C-1960/3, Type II		DATE SAMPLED	
COMPANY Ideal	LOCATION Fort Collins, CO	BRAND	
THIS CEMENT DOES MEET SPECIFICATION REQUIREMENTS			

SAMPLE NO. (Analysis)	1 (WET)	1 (AA)			1 (AA)			
SiO_2, %	21.8				TiO_2%	0.14		
Al_2O_3, %	3.7	3.2			Mn_2O_3	0.20		
Fe_2O_3, %	4.4	4.3			P_2O_5	0.08	(Colormetric)	
MgO, %	1.4							
SO_3, %	2.3							
LOSS ON IGNITION, %	1.2							
ALKALIES-TOTAL AS Na_2O, %	0.57	Water Soluble Alkali as Na_2O%					0.30	
Na_2O, %	0.17						0.04	
K_2O, %	0.61						0.39	
INSOLUBLE RESIDUE, %	0.03							
CaO, %	63.8							
C_3S, %	56							
C_3A, %	2	1.1						
C_2S, %	20							
$C_3A + C_3S$, %	58							
C_4AF, %	14							
$C_4AF + 2C_3A$, %								
HEAT OF HYDRATION, 7D, CAL/G								
HEAT OF HYDRATION, 28D, CAL/G								
SURFACE AREA, SQ CM/G (A.P.)	3660							
AIR CONTENT, %	9.8							
COMP STRENGTH 3 D, PSI	3020	COMP STR, 90 D PSI			6190			
COMP STRENGTH 7 D, PSI	3980	COMP STR, 180 D PSI			6710			
COMP STRENGTH 28 D, PSI	5500	COMP STR, 365 D PSI			6480			
FALSE SET-PEN, FINAL %								
SAMPLE NO.	1							
AUTOCLAVE EXP., %	0.05							
INITIAL SET, HR:MIN	3:50							
FINAL SET, HR:MIN	6:20							
SAMPLE NO.								
AUTOCLAVE EXP., %								
INITIAL SET, HR:MIN								
FINAL SET, HR:MIN								

REMARKS

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

ENG FORM 1 MAR 72 6008-R

TO	REPORT OF TESTS OF PORTLAND CEMENT RC-755	FROM: DEPT OF ENGINEERS ARMY Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Group P.O. Box 631 Vicksburg, MS 39180

TEST REPORT NO	DATE	AT REQUEST OF	DATE
SPECIFICATION Type V		DATE SAMPLED	
COMPANY Canada Cement	AT Manitoba, Canada	BRAND	
THIS CEMENT DOES / MUST MEET SPECIFICATION REQUIREMENTS			

SAMPLE NO (Analysis)	1(WET)	1(AA)		1(AA)			
SiO_2 %	23.7			TiO_2%	0.10		
Al_2O_3 %	2.8	2.7		Mn_2O_3	0.03		
Fe_2O_3 %	4.2	3.9		P_2O_5	0.04 (Colormetric)		
MgO %	1.4						
SO_3 %	1.4						
LOSS ON IGNITION %	1.1						
ALKALIES-TOTAL AS Na_2O %	0.56	Water Soluble Alkali as Na_2O%					0.28
Na_2O %	0.30						0.03
K_2O %	0.40						0.38
INSOLUBLE RESIDUE %	0.13						
CaO %	65.0						
C_3S %	56						
C_3A %	0.35	0.44					
C_2S %	26						
$C_3A + C_3S$ %	56						
C_4AF %	13						
$C_4AF + 2 C_3A$ %							
HEAT OF HYDRATION 7D CAL/G							
HEAT OF HYDRATION 28D CAL/G							
SURFACE AREA SQ CM/G (AP)	3520						
AIR CONTENT %	10.0						
COMP STRENGTH 3 D PSI	1970	COMP STR. 90 D		PSI	6290		
COMP STRENGTH 7 D PSI	3130	COMP STR.180 D		PSI	6725		
COMP STRENGTH 28 D PSI	5520	COMP STR.365 D		PSI	6380		
FALSE SET %							
SAMPLE NO	1						
AUTOCLAVE EXP %	0.01						
INITIAL SET HR:MIN	2:55						
FINAL SET HR:MIN	5:15						
SAMPLE NO							
AUTOCLAVE EXP %							
INITIAL SET HR:MIN							
FINAL SET HR/MIN							

REMARKS

THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U.S. GOVERNMENT

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Group

ENG FORM 1 MAR 71 6008-R

TO:	REPORT OF TEST OF HYDRAULIC CEMENT RC-756	FROM: STRUCTURES LABORATORY USAE WATERWAYS EXPERIMENT STATION ATTN CEMENT AND POZZOLAN PO BOX 631 VICKSBURG, MISSISSIPPI 39180-0631

COMPANY: Harry T. Campbell	BIN NO.	TEST REPORT NO WES-5-76
LOCATION: Baltimore, MD	TONS REPRESENTED.	DATE 19 Jan 76
SPECIFICATION: Type I, High Alkali		DATE SAMPLED

TEST RESULTS OF THIS SAMPLE LOT [X] COMPLY [ ] DO NOT COMPLY WITH SPECIFICATION LIMITS (SEE REMARKS)

SAMPLE NO.	1 (WET)		1 (AA)		1 (AA)			
SiO_2, %	19.9				TiO_2 %	0.24		
Al_2O_3, %	6.9		6.4		Mn_2O_3 %	0.06		
Fe_2O_3, %	2.2		2.1		P_2O_5 %	0.30 (Colormetric)		
CaO, %	62.9							
MgO, %	3.0							
SO_3, %	2.9							
LOSS ON IGNITION, %	0.7							
INSOLUBLE RESIDUE, %	0.30							
Na_2O, %	0.32					0.13		
K_2O, %	1.27					1.08		
ALKALIES-TOTAL AS Na_2O, %	1.16	Water	Soluble	Alkali	as Na_2O%	0.86		
C_3S, %	48							
C_3A, %	15		13					
C_2S, %	21							
$C_3A + C_3S$, %	62							
C_4AF, %	7							
$C_4AF + 2C_3A$, %								
HEAT OF HYDRATION, 7D, CAL/G								
HEAT OF HYDRATION 28D, CAL/G								
(AP) Surface Area, SQ CM/G	4030							
AIR CONTENT, %	8.8							
COMP. STRENGTH, 3 D, PSI	3510		COMP STR, 90		D, PSI	4920		
COMP. STRENGTH, 7 D, PSI	4050		COMP STR, 180		D, PSI	5290		
COMP. STRENGTH, 28 D, PSI	4690		COMP STR, 365		D, PSI	5400		
FALSE SET-PEN. F/1.%								
SAMPLE NO.								
AUTOCLAVE EXP., %	0.10							
INITIAL SET, Hr/min	2:45							
FINAL SET, Hr/min	5:15							

REMARKS

Sample received from Mrs. Mather, Job No. 545-C526.16Ci41

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

WES FORM 1540 1 SEP 84 REPLACES ENG FORM 6008-R, 1 MAR 72, WHICH IS OBSOLETE.

TO	REPORT OF TESTS OF PORTLAND CEMENT RC-756 (2)	FROM CORPS OF ENGINEERS U. S. ARMY Structures Laboratory USAE Waterways Exp Station ATTN: Cem & Pozz Group P.O. Box 631 Vicksburg, MS 39180

TEST REPORT NO KM510(30)78	BIN NO	CWT REPRESENTED	DATE DEC 78
SPECIFICATION Type I		DATE SAMPLED	
COMPANY Harry T. Campbell	LOCATION Towson, MD	BRAND	
THIS CEMENT DOES MEET SPECIFICATION REQUIREMENTS			

SAMPLE NO (Analysis)	1(WET)	1(AA)		1(AA)				
SiO_2, %	19.9			TiO_2%	0.24			
Al_2O_3, %	6.2	5.7		Mn_2O_3	0.05			
Fe_2O_3, %	2.1	2.1		P_2O_5	0.27	(Colormetric)		
MgO, %	2.7							
SO_3, %	3.0							
LOSS ON IGNITION, %	1.0							
ALKALIES-TOTAL AS Na_2O, %	1.31							
Na_2O, %	0.28							
K_2O, %	-1.57							
INSOLUBLE RESIDUE, %	0.17							
CaO, %	62.9							
C_3S, %	52							
C_3A, %	13	12						
C_2S, %	18							
$C_3A + C_3S$, %	65							
C_4AF, %	6							
$C_4AF + 2 C_3A$, %								
HEAT OF HYDRATION 7D, CAL G								
HEAT OF HYDRATION 28D, CAL G								
SURFACE AREA, SQ CM/G (A P I)	3770							
AIR CONTENT, %	8.8							
COMP. STRENGTH, 3 D, PSI	3700							
COMP. STRENGTH, 7 D, PSI	4480							
COMP. STRENGTH, 28 D, PSI	5130							
FALSE SET-PEN. F/I, %								
SAMPLE NO.	1							
AUTOCLAVE EXP., %	0.09							
INITIAL SET, HR/MIN	2:35							
FINAL SET, HR/MIN	4:55							
SAMPLE NO.								
AUTOCLAVE EXP., %								
INITIAL SET, HR/MIN								
FINAL SET, HR/MIN								

REMARKS.

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

ENG FORM 1 MAR 72 6008-R

TO	REPORT OF TESTS OF Blended Cement RC-758(IS)	FROM CORPS OF ENGINEERS U. S. ARMY Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180

TEST REPORT NO	B N NO	QTY REPRESENTED	DATE

SPECIFICATION Type 1S — DATE SAMPLED

COMPANY Wyandotte — LOCATION Wyandotte, MI — BRAND

THIS CEMENT DOES MEET SPECIFICATION REQUIREMENTS

SAMPLE NO	1(WET)	1 (AA)		1(AA)				
SiO_2, %	22.26			TiO_2	0.26			
Al_2O_3, %	6.11	5.55		MN_2O_3	0.07			
Fe_2O_3, %	2.03	2.12		P_2O_5	0.08	(Colormetric)		
MgO, %	3.72							
SO_3, %	2.58							
LOSS ON IGNITION, %	1.13							
ALKALIES-TOTAL AS Na_2O, %	0.98	Water Soluble Alkali as Na_2O%					0.47	
Na_2O, %	0.27						0.03	
K_2O, %	1.08						0.66	
INSOLUBLE RESIDUE, %								
CaO, %	60.75							
C_3S, %								
C_3A, %								
C_2S, %								
$C_3A + C_3S$, %								
C_4AF, %								
$C_4AF + 2 C_3A$, %								
HEAT OF HYDRATION, 7D, CAL/G	71							
HEAT OF HYDRATION, 28D, CAL/G	83							
SURFACE AREA, SQ CM/G (A.P.)	4120							
AIR CONTENT, %	9.9							
COMP STRENGTH, 3 D, PSI	3130	COMP STR, 90 D, PSI			5310			
COMP STRENGTH, 7 D, PSI	4010	COMP STR, 180 D, PSI			5640			
COMP STRENGTH, 28 D, PSI	5060	COMP STR, 1 YR, PSI			No Cubes			
FALSE SET-PEN F I %								
SAMPLE NO.	1							
AUTOCLAVE EXP., %	0.12							
INITIAL SET, HR/MIN	2:55							
FINAL SET, HR/MIN	5:15							
SAMPLE NO.								
AUTOCLAVE EXP., %								
INITIAL SET, HR/MIN								
FINAL SET, HR/MIN								

REMARKS

Density 3.09 Mg/m^3
W/C 0.485
Flow 107%

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

ENG FORM 1 MAR 72 6008-R

TO

REPORT OF TEST OF HYDRAULIC CEMENT

RC-761

FROM: STRUCTURES LABORATORY
USAE WATERWAYS EXPERIMENT STATION
ATTN: CEMENT AND POZZOLAN UNIT
PO BOX 631
VICKSBURG, MISSISSIPPI 39180-0631

COMPANY: Harry T. Campbell	BIN NO.	TEST REPORT NO. WES-42-76
LOCATION: Baltimore, MD	TONS REPRESENTED:	DATE: 25 Feb 76
SPECIFICATION:		DATE SAMPLED:

TEST RESULTS OF THIS SAMPLE LOT ☐ COMPLY ☐ DO NOT COMPLY WITH SPECIFICATION LIMITS (SEE REMARKS)

SAMPLE NO.	1 (WET)		1 (AA)		1 (AA)			
SiO_2, %	19.9				TiO_2 %	0.24		
Al_2O_3, %	6.6		6.0		Mn_2O_3 %	0.06		
Fe_2O_3, %	2.1		2.0		P_2O_5 %	0.25 (Colormetric)		
CaO, %	62.9							
MgO, %	2.8							
SO_3, %	2.9							
LOSS ON IGNITION, %	0.9							
INSOLUBLE RESIDUE, %	0.10							
Na_2O, %	0.27					0.15		
K_2O, %	1.22					1.08		
ALKALIES-TOTAL AS Na_2O, %	1.07	Water	Soluble	Alkali	as Na_2O%	0.86		
C_3S, %	47							
C_3A, %	14		13					
C_2S, %	19							
$C_3A + C_3S$, %	64							
C_4AF, %	6							
$C_4AF + 2 C_3A$, %	36							
HEAT OF HYDRATION, 7D, CAL/G								
HEAT OF HYDRATION, 28D, CAL/G								
(AP) Surface Area SQ CM/G	3970							
AIR CONTENT, %	8.0							
COMP. STRENGTH, 3 D, PSI	3790							
COMP. STRENGTH, 7 D, PSI	4420							
COMP. STRENGTH, D, PSI								
FALSE SET-PEN. F/1.%								
SAMPLE NO.								
AUTOCLAVE EXP., %	0.10							
INITIAL SET, Hr/min	3:00							
FINAL SET, Hr/min	5:45							

REMARKS Sample received from Mrs. Mather; Job No. 545-C526.16C141

W. G. MILLER
Chemist
Chief, Cement and Pozzolan Test Branch

THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U. S. GOVERNMENT.

WES FORM 1540 1 SEP 84 REPLACES ENG FORM 6008-R, 1 MAR 72, WHICH IS OBSOLETE.

TO	REPORT OF TESTS OF PORTLAND CEMENT RC-763	FROM CORPS OF ENGINEERS U.S. ARMY Structures Laboratory USAE Waterways Exp Station ATTN: Cem & Pozz Group P.O. Box 631 Vicksburg, MS 39180

TEST REPORT NO. | B/L NO. | AMT REPRESENTED | DATE

SPECIFICATION Type II | DATE SAMPLED

COMPANY Arizona Cement | LOCATION Rillito, AZ | BRAND

THIS CEMENT DOES MEET SPECIFICATION REQUIREMENTS

SAMPLE NO. (Analysis)	1(WET)	1(AA)		1(AA)				
SiO_2, %	22.4			TiO_2%	0.21			
Al_2O_3, %	4.1	3.6		Mn_2O_3	0.10			
Fe_2O_3, %	2.9	3.0		P_2O_5	0.06	(Colormetric)		
MgO, %	4.2							
SO_3, %	2.0							
LOSS ON IGNITION, %	1.2							
ALKALIES-TOTAL AS Na_2O, %	0.45	Water Soluble Alkali as Na_2O%					0.15	
Na_2O, %	0.09						0.01	
K_2O, %	0.54						0.21	
INSOLUBLE RESIDUE, %	0.63							
CaO, %	62.8							
C_3S, %	48							
C_3A, %	6	4						
C_2S, %	28							
$C_3A + C_3S$, %	54							
C_4AF, %	9							
$C_4AF + 2C_3A$, %								
HEAT OF HYDRATION, 7D, CAL/G								
HEAT OF HYDRATION, 28D, CAL/G								
SURFACE AREA, SQ CM/G (A.P.)	3620							
AIR CONTENT, %	7.6							
COMP STRENGTH, 3 D, PSI	2700	COMP STR, 90 D, PSI			6210			
COMP STRENGTH, 7 D, PSI	3730	COMP STR, 180 D, PSI			7000			
COMP STRENGTH, 28 D, PSI	5500	COMP STR, 365 D, PSI			7400			
FALSE SET-PEN, FINAL %								
SAMPLE NO.	1							
AUTOCLAVE EXP., %	0.13							
INITIAL SET, HR:MIN	3:20							
FINAL SET, HR:MIN	5:45							
SAMPLE NO.								
AUTOCLAVE EXP., %								
INITIAL SET, HR:MIN								
FINAL SET, HR:MIN								

REMARKS

THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U.S. GOVERNMENT

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

ENG FORM 1 MAR 73 6008-R

TO	REPORT OF TESTS OF PORTLAND CEMENT RC-764	FROM: CORPS OF ENGINEERS U S ARMY Structures Laboratory USAE Waterways Exp Station ATTN: Cem & Pozz Test Br P.O. Box 631 Vicksburg, MS 39180

TEST REPORT NO | BIN NO | CWT REPRESENTED | DATE

SPECIFICATION Type II | DATE SAMPLED

COMPANY Arizona Cement | LOCATION Rillito, AZ | BRAND

THIS CEMENT DOES MEET SPECIFICATION REQUIREMENTS

SAMPLE NO (Analysis)	1(WET)	1(AA)		1(AA)				
SiO_2, %	23.1			TiO_2%	0.19			
Al_2O_3, %	3.8	3.3		Mn_2O_3	0.10			
Fe_2O_3, %	3.1	3.1		P_2O_5	0.08	(Colormetric)		
MgO, %	4.5							
SO_3, %	2.0							
LOSS ON IGNITION, %	1.0							
ALKALIES-TOTAL AS Na_2O, %	0.47	Water	Soluble	Alkali	as Na_2O%		0.27	
Na_2O, %	0.11						0.03	
K_2O, %	0.55						0.36	
INSOLUBLE RESIDUE, %	0.63							
CaO, %	62.7							
C_3S, %	44							
C_3A, %	5	4						
C_2S, %	33							
$C_3A + C_3S$, %	49							
C_4AF, %	9							
$C_4AF + 2C_3A$, %								
HEAT OF HYDRATION, 7D, CAL/G								
HEAT OF HYDRATION, 28D, CAL/G								
SURFACE AREA, SQ CM/G (A P I)	3780							
AIR CONTENT, %	8.6							
COMP STRENGTH, 3 D, PSI	2750	COMP STR,	90	D, PSI	6250			
COMP STRENGTH, 7 D, PSI	3630	COMP STR,	180	D, PSI	7130			
COMP STRENGTH, 28 D, PSI	5150	COMP STR,	365	D, PSI	7250			
FALSE SET-PEN, F I, %								
SAMPLE NO	1							
AUTOCLAVE EXP., %	0.13							
INITIAL SET, HR:MIN	3:25							
FINAL SET, HR:MIN	6:25							
SAMPLE NO								
AUTOCLAVE EXP., %								
INITIAL SET, HR:MIN								
FINAL SET, HR:MIN								

REMARKS

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

ENG FORM 1 MAR 72 6008-R

*CORRECTION

TO		FROM CORPS OF ENGINEERS U. S. ARMY
Mrs. K. Mather Ch, Petro & X-Ray Engr Sci Div CL	REPORT OF TESTS OF *PORTLAND CEMENT* RC 765 and RC 766	Cem & Pozz Test Br Engr Sci Div CL

TEST REPORT NO. WES-149-76	BIN NO.	CWT REPRESENTED.	DATE 15 Jun 76
SPECIFICATION SS-C-1960/3		DATE SAMPLED	
COMPANY Sementsverksmidja	LOCATION Akranesi, Iceland	BRAND	
THIS CEMENT DOES MEET SPECIFICATION REQUIREMENTS			

	SAMPLE NO.	RC-765		RC-766					
	SiO_2, %	19.7		20.2					
	Al_2O_3, %	5.4		5.4					
	Fe_2O_3, %	3.1		3.2					
	MgO, %	2.3		2.3					
	SO_3, %	3.4		2.8					
	LOSS ON IGNITION, %	1.5		1.0					
*	ALKALIES-TOTAL AS Na_2O, %	1.40		1.38					
*	Na_2O, %	1.25		1.28					
	K_2O, %	0.23		0.19					
	INSOLUBLE RESIDUE, %	0.41		0.39					
	CaO, %	63.3		63.6					
	C_3S, %	57.7		56.7					
	C_3A, %	9.1		9.0					
	C_2S, %	13.0		15.0					
	$C_3A + C_3S$, %	66.7		65.7					
	C_4AF, %	9.3		9.7					
	$C_4AF + 2C_3A$, %	27.5		27.7					
	HEAT OF HYDRATION, 7D, CAL/G								
	HEAT OF HYDRATION, 28D, CAL/G								
	SURFACE AREA, SQ CM/G (A.P.)	2770		2950					
	AIR CONTENT, %			10.8					
	COMP. STRENGTH, 3 D, PSI			2920					
	COMP. STRENGTH, 7 D, PSI			3460					
	COMP. STRENGTH, 28 D, PSI			4230					
	Specific Gravity	3.11		3.14					
	SAMPLE NO.			RC-766					
	AUTOCLAVE EXP., %			0.08					
	INITIAL SET, HR/MIN			3:10					
	FINAL SET, HR/MIN			6:05					
	SAMPLE NO.								
	AUTOCLAVE EXP., %								
	INITIAL SET, HR/MIN								
	FINAL SET, HR/MIN								

REMARKS: Insufficient quantity of RC-765 to run all physical tests. Run Insol on both to determine which is PC and PP. Run all tests, chemical and physical (no HH) on RC-766. RC-766 had 0.3% gypsum added to the clinker. Volcanic ash could be pozzolan in PP cement. Job No. 545-C526.16C141 ($500). (Comparison of the test data indicates both were portland cement (5/20/86).)

*Correction issued to indicate correct values for alkali and Na2O

W. G. Miller

W. G. MILLER
Chemist
Chief, Cement and Pozzolan Test Branch

ENG FORM 6005-R

TO	REPORT OF TESTS OF Blended Cement RC-769	FROM CORPS OF ENGINEERS U.S. ARMY Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180

TEST REPORT NO	BIN NO	CWT REPRESENTED	DATE
SPECIFICATION Type 1S		DATE SAMPLED	
COMPANY Universal Atlas	LOCATION Universal, PA	BRAND	

THIS CEMENT DOES MEET SPECIFICATION REQUIREMENTS

SAMPLE NO	1(WET)	1 (AA)		1(AA)				
SiO_2 %	23.92			TiO_2	0.34			
Al_2O_3 %	7.91	6.35		MN_2O_3	0.35			
Fe_2O_3 %	2.19	2.33		P_2O_5	0.17			
MgO %	4.92							
SO_3 %	2.42							
LOSS ON IGNITION, %	2.00							
ALKALIES-TOTAL AS Na_2O %	0.37	Water Soluble Alkali as Na_2O%					0.04	
Na_2O %	0.19						0.02	
K_2O %	0.27						0.03	
INSOLUBLE RESIDUE %								
CaO %	55.75							
C_3S %								
C_3A %								
C_2S %								
$C_3A + C_3S$ %								
C_4AF %								
$C_4AF + 2\ C_3A$ %								
HEAT OF HYDRATION, 7D CAL/G	80							
HEAT OF HYDRATION, 28D CAL/G	90							
SURFACE AREA SQ CM/G (A.P.)	5380							
AIR CONTENT %	7.1							
COMP STRENGTH, 3D PSI	3910	COMP STR, 90 D, PSI			8610			
COMP STRENGTH, 7D PSI	5430	COMP STR, 180 D, PSI			8210			
COMP STRENGTH, 28D PSI	7920	COMP STR, 1 YR, PSI			8460			
FALSE SET-PEN FINAL %								
SAMPLE NO	1							
AUTOCLAVE EXP, %	0.10							
INITIAL SET, HR MIN	2:25							
FINAL SET, HR MIN	5:40							
SAMPLE NO								
AUTOCLAVE EXP, %								
INITIAL SET, HR MIN								
FINAL SET, HR/MIN								

REMARKS

Density 3.03 Mg/m^3
W/C 0.485
Flow 110%

THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U.S. GOVERNMENT

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

ENG FORM 6008-R
1 MAR 72

TO	REPORT OF TESTS OF PORTLAND CEMENT RC-770	FROM CORPS OF ENGINEERS U. S. ARMY Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P.O. Box 631 Vicksburg, MS 39180

TEST REPORT NO	BIN NO	AMT REPRESENTED	DATE
SPECIFICATION Type I		DATE SAMPLED	
COMPANY Universal Atlas	LOCATION Universal, PA	BRAND	
THIS CEMENT DOES MEET SPECIFICATION REQUIREMENTS			

SAMPLE NO (Analysis)	1(WET)	1(AA)		1(AA)				
SiO_2, %	20.4			TiO_2%	0.30			
Al_2O_3, %	5.8	5.2		Mn_2O_3	0.23			
Fe_2O_3, %	2.3	2.4		P_2O_5	0.05	(Colormetric)		
MgO %	3.9							
SO_3 %	2.4							
LOSS ON IGNITION, %	2.2							
ALKALIES-TOTAL AS Na_2O %	0.33	Water	Soluble	Alkali	as Na_2O%		0.10	
Na_2O %	0.17						0.03	
K_2O %	0.24						0.11	
INSOLUBLE RESIDUE %	0.29							
CaO %	62.9							
C_3S %	52							
C_3A %	11	10						
C_2S %	19							
$C_3A + C_3S$ %	64							
C_4AF %	7							
$C_4AF + 2\ C_3A$ %								
HEAT OF HYDRATION 7 DAYS	84							
HEAT OF HYDRATION 28 DAYS	93							
SURFACE AREA SQ CM/G AP	4270							
AIR CONTENT %	9.2							
COMP STRENGTH 3 D PSI	3170	COMP STR,	90	D, PSI	7150			
COMP STRENGTH 7 D PSI	4740	COMP STR,	180	D, PSI	7120			
COMP STRENGTH 28 D PSI	6850	COMP STR,	365	D, PSI	7170			
FALSE SET PEN								
SAMPLE NO	1							
AUTOCLAVE EXP	0.17							
INITIAL SET HR MIN	3:20							
FINAL SET HR MIN	4:25							
SAMPLE NO								
AUTOCLAVE EXP								
INITIAL SET HR MIN								
FINAL SET HR MIN								

REMARKS

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Brahch

ENG FORM 1 MAR 72 4008-R

TO	REPORT OF TESTS OF PORTLAND CEMENT RC-772	FROM CORPS OF ENGINEERS U. S. ARMY Cem & Pozz Test Br Engr Sci Div CL

TEST REPORT NO	B. NO	CWT REPRESENTED 1 Sample	DATE 11 Feb 77
SPECIFICATION Type II		DATE SAMPLED	
COMPANY Monarch	LOCATION Humboldt, KS	BRAND	
THIS CEMENT DOES MEET SPECIFICATION REQUIREMENTS			

SAMPLE NO. (Analysis)	1(WET)	1(AA)		1(AA)				
SiO_2, %	21.2			TiO_2%	0.29			
Al_2O_3, %	4.7	4.3		Mn_2O_3	0.12			
Fe_2O_3, %	3.1	3.2		P_2O_5	0.07	(Colormetric)		
MgO, %	2.0							
SO_3, %	2.3							
LOSS ON IGNITION, %	1.4							
ALKALIES-TOTAL AS Na_2O, %	0.64	Water	Soluble	Alkali	as Na_2O%		0.12	
Na_2O, %	0.20						0.02	
K_2O, %	0.67						0.16	
INSOLUBLE RESIDUE, %	0.17							
CaO, %	64.2							
C_3S, %	58							
C_3A, %	7	6						
C_2S, %	17							
$C_3A + C_3S$, %	65							
C_4AF, %	10							
$C_4AF + 2C_3A$, %	24							
HEAT OF HYDRATION, 7D, CAL/G								
HEAT OF HYDRATION, 28D, CAL/G								
SURFACE AREA, SQ CM/G (A.P.I)	3610							
AIR CONTENT, %	9.9							
COMP STRENGTH, 3 D, PSI	2660	COMP STR,	90D	PSI	5990			
COMP STRENGTH, 7 D, PSI	3540	COMP STR,	180D	PSI	6460			
COMP STRENGTH 28 D, PSI	5390	COMP STR.	365D	PSI	6320			
FALSE SET-PEN. F. I. %								
SAMPLE NO.	1							
AUTOCLAVE EXP., %	0.01							
INITIAL SET, HR/MIN	3:25							
FINAL SET, HR/MIN	5:50							
SAMPLE NO								
AUTOCLAVE EXP., %								
INITIAL SET, HR/MIN								
FINAL SET, HR/MIN								

REMARKS Memorandum No. 1965; Job No. 545-C530.17C141

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

ENG FORM 1 MAR 73 6008-R

TO	REPORT OF TESTS OF Blended Cement RC-773	FROM CORPS OF ENGINEERS U. S. ARMY Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180

TEST REPORT NO | BIN NO | CWT REPRESENTED | DATE

SPECIFICATION 1-P | DATE SAMPLED

COMPANY Texas Industries | LOCATION Midlothian, TX | BRAND

THIS CEMENT DOES MEET SPECIFICATION REQUIREMENTS

SAMPLE NO	1(WET)	1 (AA)		1(AA)				
SiO_2, %	24.99			TiO_2	0.57			
Al_2O_3, %	10.03	7.41		MN_2O_3	0.24			
Fe_2O_3, %	3.33	3.17		P_2O_5	0.20	(Colormetric)		
MgO, %	1.39							
SO_3, %	3.64							
LOSS ON IGNITION, %	1.38							
ALKALIES-TOTAL AS Na_2O, %	0.53	Water Soluble Alkali as Na_2O%					0.34	
Na_2O, %	0.17						0.06	
K_2O, %	0.54						0.41	
INSOLUBLE RESIDUE, %								
CaO, %	54.46							
C_3S, %								
C_3A, %								
C_2S, %								
$C_3A + C_3S$, %								
C_4AF, %								
$C_4AF + 2C_3A$, %								
HEAT OF HYDRATION, 7D, CAL/G								
HEAT OF HYDRATION, 28D, CAL/G								
SURFACE AREA, SQ CM/G (A P I)	3940							
AIR CONTENT, %	6.0							
COMP STRENGTH 3 D, PSI	3480	COMP STR, 90 D, PSI			7260			
COMP STRENGTH 7 D, PSI	4350	COMP STR, 180 D, PSI			8300			
COMP STRENGTH 28 D, PSI	5910	COMP STR, 1 YR, PSI			9410			
FALSE SET-PEN. F. %								
SAMPLE NO.	1							
AUTOCLAVE EXP., %	0.03							
INITIAL SET, HR/MIN	4:00							
FINAL SET, HR/MIN	5:20							
SAMPLE NO								
AUTOCLAVE EXP., %								
INITIAL SET, HR/MIN								
FINAL SET, HR/MIN								

REMARKS

Density 3.04 Mg/m^3
W/C 0.448
Flow 110%

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

ENG FORM 1 MAR 72 6008-R

Mrs. K. Mather
C/Engr Sci Div
Structures Laboratory

REPORT OF TESTS OF PORTLAND CEMENT

RC-807

FROM CORPS OF ENGINEERS U.S. ARMY
Structures Laboratory
USAE Waterways Exp Sta
P. O. Box 631
Vicksburg, MS 39180

TEST REPORT NO WES-295-78 | BIN NO | CMT REPRESENTED 1 Sample | DATE 25 Aug 78

SPECIFICATION SS-C-1960/4, Type I P, MS | DATE SAMPLED

COMPANY TXI | LOCATION Midlothian, TX | BRAND

THIS CEMENT DOES MEET SPECIFICATION REQUIREMENTS

SAMPLE NO	WET RC-807	AA RC-807		AA RC-807				
SiO_2, %	25.28			TiO_2	0.41			
Al_2O_3, %	8.06	6.83		MN_2O_3	0.34			
Fe_2O_3, %	4.60	4.76		P_2O_5	0.16	Colormetric		
MgO, %	1.63							
SO_3, %	2.71							
LOSS ON IGNITION, %	0.48							
ALKALIES-TOTAL AS Na_2O, %	0.48							
Na_2O, %	0.23							
K_2O, %	0.38							
INSOLUBLE RESIDUE, %	8.40							
CaO, %	58.10							
C_3S, %								
C_3A, %								
C_2S, %								
$C_3A + C_3S$, %								
C_4AF, %								
$C_4AF + 2C_3A$, %								
HEAT OF HYDRATION, 7D, CAL/G	76							
* HEAT OF HYDRATION, 28D, CAL/G	87							
SURFACE AREA, SQ CM/G (A.P.)	3990							
AIR CONTENT, %	8.0							
COMP. STRENGTH, 3D, PSI	3800	*	Comp Str, 56 D, PSI			7830		
COMP. STRENGTH, 7D, PSI	5130	*	Comp Str, 90 D, PSI			9180		
* COMP. STRENGTH, 28D, PSI	6940	*	Comp Str, 180 D, PSI			9390		
FALSE SET-PEN. FIN. %		*	Comp Str, 365 D, PSI			10400		
SAMPLE NO.	1							
AUTOCLAVE EXP., %	-0.04							
INITIAL SET, HR/MIN	3:15							
FINAL SET, HR/MIN	5:20							
SAMPLE NO.								
AUTOCLAVE EXP., %	325(45μm) Sieve: 4% retained.							
INITIAL SET, HR/MIN								
FINAL SET, HR/MIN								

* REMARKS Test results will be reported upon completion of tests.

THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U.S. GOVERNMENT

for W.G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

ENG FORM 1 MAR 72 6008-R

TO	REPORT OF TESTS OF PORTLAND CEMENT	FROM: CORPS OF ENGINEERS U.S. ARMY
Mrs. K. Mather C/Engrg Sci Div Structures Laboratory	RC-807(A)	Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P.O. Box 631 Vicksburg, MS 39180

TEST REPORT NO. WES-295-78	B/L NO.	AMT REPRESENTED 1 sample	DATE 24 Nov 78
SPECIFICATION I		DATE SAMPLED	
COMPANY TXI	LOCATION Midlothian, TX	BRAND	
THIS CEMENT DOES	MEET SPECIFICATION REQUIREMENTS		

SAMPLE NO.	RC-807(A)							
SiO_2, %	20.56							
Al_2O_3, %	5.08							
Fe_2O_3, %	4.06							
MgO, %	0.86							
SO_3, %	2.53							
LOSS ON IGNITION, %	0.99							
ALKALIES-TOTAL AS Na_2O, %	0.27							
Na_2O, %	0.11							
K_2O, %	0.25							
INSOLUBLE RESIDUE, %	0.17							
CaO, %	65.69							
C_3S, %	64.02							
C_3A, %	6.59							
C_2S, %	10.65							
$C_3A + C_3S$, %	70.61							
C_4AF, %	12.35							
$C_4AF + 2C_3A$, %	25.53							
HEAT OF HYDRATION, 7D, CAL/G								
HEAT OF HYDRATION, 28D, CAL/G								
SURFACE AREA, SQ CM/G (A.P.)								
AIR CONTENT, %								
COMP. STRENGTH, D, PSI								
COMP. STRENGTH, D, PSI								
COMP. STRENGTH, D, PSI								
FALSE SET-PEN, %								
SAMPLE NO.								
AUTOCLAVE EXP., %								
INITIAL SET, HR:MIN								
FINAL SET, HR:MIN								
SAMPLE NO.								
AUTOCLAVE EXP., %								
INITIAL SET, HR:MIN								
FINAL SET, HR:MIN								

REMARKS Ref ltr from TXI, Midlothian, TX dtd 4/5/78. This cement blended with AD-577 to make RC-807, IP, MS. Sample Size approximately 4 oz.

THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U.S. GOVERNMENT

for W.G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

ENG FORM 1 MAR 72 4048 R

TO		FROM CORPS OF ENGINEERS U.S. ARMY
Structures Laboraotry USAE Waterways Exp Stat ATTN: Katharine Mather Vicksburg, MS 39180	REPORT OF TESTS OF PORTLAND CEMENT RC-829	Structures Laboratory Waterways Exp Station ATTN: Cem & Pozz Group P.O. Box 631 Vicksburg, MS 39180

TEST REPORT NO.	BIN NO.	DATE RECEIVED	DATE 16 April 80
SPECIFICATION SS-C-1960/3, Type I		DATE SAMPLED	
COMPANY Dundee	LOCATION Dundee, MI		BRAND
THIS CEMENT DOES	MEET SPECIFICATION REQUIREMENTS		

SAMPLE NO.	WET	AA	AA			
SiO_2	20.9		TiO_2	0.23		
Al_2O_3	5.1	4.68	MN_2O_3	0.04		
Fe_2O_3	2.8	2.7	P_2O_5	0.06	Colorimetric	
MgO	4.0					
SO_3	2.54					
LOSS ON IGNITION	1.03					
ALKALIES TOTAL AS Na_2O	0.80					
Na_2O	0.33					
K_2O	0.71					
INSOLUBLE RESIDUE	0.42					
CaO	63.0					
C_3S	55					
C_3A	8.7	7.8				
C_2S	18					
$C_3A + C_3S$	64					
C_4AF	8.5					
$C_4AF + 2C_3A$	26					
HEAT OF HYDRATION 7 DAYS						
HEAT OF HYDRATION 28 DAYS						
SURFACE AREA						
AIR CONTENT						
COMP STRENGTH						
COMP STRENGTH						
COMP STRENGTH						
FALSE SET						
SAMPLE NO.						
AUTOCLAVE EXP						
INITIAL SET HR MIN						
FINAL SET HR MIN						
SAMPLE NO.						
AUTOCLAVE EXP %						
INITIAL SET HR MIN						
FINAL SET HR MIN						

REMARKS

THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U.S. GOVERNMENT

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Group

ENG FORM 6008-R

TO		FROM CORPS OF ENGINEERS U.S. ARMY
Structures Laboraotry USAE Waterways Exp St ATTN: Katharine Mather Vicksburg, MS 39180	**REPORT OF TESTS OF PORTLAND CEMENT** RC-830	Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Group P.O. Box 631 Vicksburg, MS 39180

TEST REPORT NO	BIN NO	CWT REPRESENTED	DATE 16 April 80
SPECIFICATION SS-C-1960/4, Type IP		DATE SAMPLED	
COMPANY Dundee	LOCATION Dundee, MI	BRAND	

THIS CEMENT DOES MEET SPECIFICATION REQUIREMENTS

SAMPLE NO	WET		AA		AA			
SiO_2, %	26.8				TiO_2	0.51		
Al_2O_3, %	10.7		10.0		MN_2O_3	0.04		
Fe_2O_3, %	3.6		3.6		P_2O_5	0.10	Colormetric	
MgO, %	3.1							
SO_3, %	2.12							
LOSS ON IGNITION, %	1.74							
ALKALIES-TOTAL AS Na_2O, %			1.17					
Na_2O, %			0.33					
K_2O, %			1.28					
MOISTURE	0.41							
CaO, %	49.8							
C_3S, %								
C_3A, %								
C_2S, %								
$C_3A + C_3S$, %								
C_4AF, %								
$C_4AF + 2C_3A$, %								
HEAT OF HYDRATION, 7D, CAL/G								
HEAT OF HYDRATION, 28D, CAL/G								
SURFACE AREA, SQ CM/G (A.P.)								
AIR CONTENT, %								
COMP. STRENGTH D, PSI								
COMP. STRENGTH D, PSI								
COMP. STRENGTH D, PSI								
FALSE SET-PEN., F, %								
SAMPLE NO								
AUTOCLAVE EXP., %								
INITIAL SET, HR:MIN								
FINAL SET, HR:MIN								
SAMPLE NO								
AUTOCLAVE EXP., %								
INITIAL SET, HR:MIN								
FINAL SET, HR:MIN								

REMARKS

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Group

ENG FORM 1 MAR 72 6008-R

TO	REPORT OF TESTS OF PORTLAND CEMENT	FROM: CORPS OF ENGINEERS U.S. ARMY
Structures Laboraotry USAE Waterways Exp Stat ATTN: Katharine Mather Vicksburg, MS 39180	RC-831	Structures Laboratory USAE Waterways Exp Station ATTN: Cem & Pozz Group P.O. Box 631 Vicksburg, MS 39180

TEST REPORT NO. | BIN NO. | AMT REPRESENTED | DATE 16 April 80

SPECIFICATION SS-C-1960/3, Type II | DATE SAMPLED

COMPANY PCA-LTS 21 | LOCATION | BRAND

THIS CEMENT DOES MEET SPECIFICATION REQUIREMENTS

SAMPLE NO.	WET		AA		AA				
SiO_2, %	23.7				TiO_2	0.20			
Al_2O_3, %	4.6		3.97		MN_2O_3	0.05			
Fe_2O_3, %	3.2		3.1		P_2O_5	0.16	Colormetric		
MgO, %	1.24								
SO_3, %	1.22								
LOSS ON IGNITION, %	0.95								
ALKALIES-TOTAL AS Na_2O, %	0.54								
Na_2O, %	0.26								
K_2O, %	0.43								
INSOLUBLE RESIDUE, %	0.37								
CaO, %	64.3								
C_3S, %	43								
C_3A, %	6.7		5.3						
C_2S, %	35								
$C_3A + C_3S$, %	50								
C_4AF, %	9.7								
$C_4AF + 2C_3A$, %	23								
HEAT OF HYDRATION, 7D, CAL/G									
HEAT OF HYDRATION, 28D, CAL/G									
SURFACE AREA, SQ CM/G (A.P.)									
AIR CONTENT, %									
COMP. STRENGTH, D, PSI									
COMP. STRENGTH, D, PSI									
COMP. STRENGTH, D, PSI									
FALSE SET-PEN. F.I. %									
SAMPLE NO.									
AUTOCLAVE EXP., %									
INITIAL SET, HR/MIN									
FINAL SET, HR/MIN									
SAMPLE NO.									
AUTOCLAVE EXP., %									
INITIAL SET, HR/MIN									
FINAL SET, HR/MIN									

REMARKS

THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U.S. GOVERNMENT

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Group

ENG FORM 1 MAR 71 6008-R

TO	REPORT OF TESTS OF PORTLAND CEMENT	FROM
Structures Laboraotry USAE Waterways Exp St ATTN: Katharine Mather Vicksburg, MS 39180	RC-832	Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Group P.O. Box 631 Vicksburg, MS 39180

TEST REPORT NO. | B/N | ATTN | DATE 16 April 80

SPECIFICATION SS-C-1960/3, Type V | ATC SAMPLE

COMPANY Ideal | LOCATION Ft. Collins, CO | BRAND

THIS CEMENT DOES | MEET SPECIFICATION REQUIREMENTS

SAMPLE NO.	WET		AA	AA			
SiO_2, %	22.6			TiO_2	0.11		
Al_2O_3, %	3.3		3.0	MN_2O_3	0.15		
Fe_2O_3, %	5.3		5.2	P_2O_5	0.12	Colormetric	
MgO, %	1.3						
SO_3, %	1.76						
LOSS ON IGNITION, %	1.22						
ALKALIES—TOTAL AS Na_2O, %	0.54						
Na_2O, %	0.18						
K_2O, %	0.55						
INSOLUBLE RESIDUE, %	0.28						
CaO, %	63.3						
C_3S, %							
C_3A, %							
C_2S, %							
$C_3A + C_3S$, %							
C_4AF, %							
$C_4AF + C_2F$)	16		15				
HEAT OF HYDRATION 7D, CAL/G							
HEAT OF HYDRATION 28D, CAL/G							
SURFACE AREA, SQ CM/G (A.P.)							
AIR CONTENT, %							
COMP. STRENGTH D, PSI							
COMP. STRENGTH D, PSI							
COMP. STRENGTH D, PSI							
FALSE SET—PEN. F/I, %							
SAMPLE NO.							
AUTOCLAVE EXP., %							
INITIAL SET, HR/MIN							
FINAL SET, HR/MIN							
SAMPLE NO.							
AUTOCLAVE EXP., %							
INITIAL SET, HR/MIN							
FINAL SET, HR/MIN							

REMARKS

THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U.S. GOVERNMENT

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Group

ENG FORM 1 MAR 72 6008-R

Structures Laboraotry USAE Waterways Exp St ATTN: Kathrine Mather Vicksburg, MS 39180	**REPORT OF TESTS OF PORTLAND CEMENT** RC-833	FROM CORPS OF ENGINEERS U.S. ARMY Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Group P.O. Box 631 Vicksburg, MS 39180

[illegible]	BIN NO	QUANTITY REPRESENTED	DATE 16 April 80
SPECIFICATION SS-C-1960/4, Type IS		DATE SAMPLED	
COMPANY Universal Atlas	LOCATION Pittsburgh, PA	BRAND	
THIS CEMENT DOES MEET SPECIFICATION REQUIREMENTS			

SAMPLE NO	WET		AA		AA			
SiO_2	24.5				TiO_2	0.27		
Al_2O_3, %	7.2		6.8		MN_2O_3	0.31		
Fe_2O_3, %	2.0		2.1		P_2O_5	0.20	Colormetric	
MgO, %	6.3							
SO_3, %	2.49							
LOSS ON IGNITION, %	3.02							
ALKALIES-TOTAL AS Na_2O, %	0.34							
Na_2O, %	0.19							
K_2O, %	0.23							
INSOLUBLE RESIDUE, %								
CaO, %	53.2							
C_3S, %								
C_3A, %								
C_2S, %								
$C_3A + C_3S$, %								
C_4AF, %								
$C_4AF + 2\ C_3A$, %								
HEAT OF HYDRATION, 7D, CAL/G								
HEAT OF HYDRATION, 28D, CAL/G								
SURFACE AREA, SQ CM/G (A.P.)								
AIR CONTENT, %								
COMP. STRENGTH, D, PSI								
COMP. STRENGTH, D, PSI								
COMP. STRENGTH, D, PSI								
FALSE SET-PEN. F								
SAMPLE NO								
AUTOCLAVE EXP., %								
INITIAL SET, HR/MIN								
FINAL SET, HR/MIN								
SAMPLE NO								
AUTOCLAVE EXP., %								
INITIAL SET, HR/MIN								
FINAL SET, HR/MIN								

REMARKS

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Group

ENG FORM 1 MAR 72 6008-R

TO:	REPORT OF TEST OF HYDRAULIC CEMENT RC-834	FROM: STRUCTURES LABORATORY USAE WATERWAYS EXPERIMENT STATION ATTN: CEMENT AND POZZOLAN PO BOX 631 VICKSBURG, MISSISSIPPI 39180-0631

COMPANY: Penn-Dixie	BIN NO.	TEST REPORT NO WES-568-79
LOCATION: Nazarith, PA	TONS REPRESENTED:	DATE 30 Nov 79
SPECIFICATION: Type I		DATE SAMPLED 11 Oct 79

TEST RESULTS OF THIS SAMPLE LOT ☐ COMPLY ☐ DO NOT COMPLY WITH SPECIFICATION LIMITS (SEE REMARKS)

SAMPLE NO.	WET		AA					
SiO_2, %	19.1							
Al_2O_3, %	7.0		5.8					
Fe_2O_3, %	2.6		2.5					
CaO, %	62.7							
MgO, %	3.1		2.9					
SO_3, %	2.8							
LOSS ON IGNITION, %	1.4							
INSOLUBLE RESIDUE, %	0.21							
Na_2O, %	0.34							
K_2O, %	0.98							
ALKALIES-TOTAL AS Na_2O, %	0.92							
C_3S, %	52							
C_3A, %	14		12					
C_2S, %	16							
$C_3A + C_3S$, %	66							
C_4AF, %	8							
$C_4AF + 2C_3A$, %	36							
HEAT OF HYDRATION, 7D, CAL/G								
HEAT OF HYDRATION, 28D, CAL/G								
(AP) Surface Area, SQ CM/G	4160							
AIR CONTENT, %	11.0							
COMP. STRENGTH, 3 D, PSI	3090							
COMP. STRENGTH, 7 D, PSI	4130							
COMP. STRENGTH, 28 D, PSI	4500							
FALSE SET-PEN. F/1.%								
SAMPLE NO.								
AUTOCLAVE EXP., %	0.03							
INITIAL SET, Hr/min	3:00							
FINAL SET, Hr/min	5:05							

REMARKS Job No. 508-S530 & S527.19Si41

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

WES FORM 1 SEP 84 1530   REPLACES ENG FORM 6008-R, 1 MAR 72, WHICH IS OBSOLETE.

Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180	REPORT OF TESTS ON POZZOLAN	Report No: Admixture No: AD 505 Date:

POZZOLAN CLASS: F	DESCRIPTION: Subbituminous Fly Ash
COMPANY: Kansas City P & L Co	LOCATION: Hawthorne Plant, Kansas City, MO
MEMO NO: 1985 DATE: 10/6/75	JOB NO: 545-C-530
MEMO SUBJECT: Variations in Cementitious Media	

CHEMICAL COMPOSITION

SiO_2 %	45.68	Moisture Content %	0.14	Cr_2O_3 %	
Al_2O_3 %	21.44	LOI, % (750 C)	3.81	Chloride %	
Fe_2O_3 %	10.88	LOI, % (1000 C)			
MgO %	2.50	TiO_2 %			
SO_3 %	1.11	P_2O_5 %			
CaO %	11.11	Mn_2O_3 %			

Alkalies %	Water Soluble	Available (C-618)	Acid Soluble	Total Alkali
Na_2O %	0.01	0.12	0.04	0.37
K_2O %	0.01	0.60	0.20	1.93
Total as Na_2O%	0.02	0.51	0.17	1.64

PHYSICAL TESTS

Specific Gravity: 2.44 | Fineness % retained on 325 Sieve

Surface Area: 9130 sqcm/cc, porosity e = 0.416

Tests with portland cement cured @ 73.4 $\pm$ 3 F

Portland Cement Co:	United			Citadel		
Location:	Artesia, MS			Birmingham, AL		
Research Cement No & Type:	RC-688 I, LA			RC-705, II, LA, HH		
Autoclave Expansion, 20% Replacement, %	0.01			0.07		
% Replace of Cement by Volume	0	30	60	0	30	60
Heat of Hydration, 7 days, Cal/gm	84.8	70.2	49	67.7	56.4	46.8
Heat of Hydration, 28 days, Cal/gm	96.5	83.2	62	78.8	65.4	56.5
Compressive Strength, 3 days psi	2880	2320	690	1700	1450	730
Compressive Strength, 7 days psi	4080	3010	930	2510	1880	920
Compressive Strength, 28 days psi	5320	4530	1290	4040	2910	1380
Compressive Strength, 90 days psi	5860	6060	4200	5760	5320	2600
Compressive Strength, 180 days psi	6050	6760	4770	5990	6610	4010
Compressive Strength, 365 days psi		6760	5860		6060	4840
Water - Cement Ratio	0.485	0.485	0.485	0.485	0.485	0.485
Flow	111	108	110	122	111	103

Pozzolanic Activity Index, ASTM C618
With Lime @ 7 days PSI 1790
With Portland Cement (RC-688) at 28 days percent of Control 113

<u>Test for Pozzolan Hydraulic Activity</u>

Compressive Strength (PSI)

W/C	3days	7days	28days
0.417	55	70	160

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180	REPORT OF TESTS ON POZZOLAN	Report No: Admixture No: AD 506 Date:

POZZOLAN CLASS: F | DESCRIPTION: Lignite Fly Ash

COMPANY: Trinity (Gen Port) | LOCATION: Big Brown Plant, Fairfield, TX

MEMO NO: 1985 | DATE: 10/6/75 | JOB NO: 545-C-530

MEMO SUBJECT: Variations in Cementitious Media

CHEMICAL COMPOSITION

SiO_2 %	50.4	Moisture Content %	0.17	Cr_2O_3 %	
Al_2O_3 %	18.41	LOI, % (750°C)	0.85	Chloride %	
Fe_2O_3 %	4.16	LOI, % (1000°C)			
MgO %	3.54	TiO_2 %			
SO_3 %	1.30	P_2O_5 %			
CaO %	19.77	Mn_2O_3 %			

Alkalies	Water Soluble	Available (C-618)	Acid Soluble	Total Alkali
Na_2O %	0.00	0.21	0.20	0.57
K_2O %	0.00	0.18	0.12	0.53
Total as Na_2O %	0.00	0.33	0.28	0.92

PHYSICAL TESTS

Specific Gravity: 2.56 | Fineness: % retained on 325 Sieve

Surface Area: 6760 sqcm/cc, porosity e= 0.390

Tests with portland cement cured @ 73.4 ± 3° F

Portland Cement Co.:	United			Citadel		
Location:	Artesia, MS			Birmingham, AL		
Research Cement No & Type:	RC-688, I,			RC-705, II, LA, HH		
Autoclave Expansion, 20% Replacement, %	0.04			0.09		
% Replace of Cement by Volume	0	30	60	0	30	60
Heat of Hydration, 7 days, Cal/gm	84.8	72.9	53	67.7	55.6	45
Heat of Hydration, 28 days, Cal/gm	96.5	85.4	67	78.8	70.3	57
Compressive Strength, 3 days psi	2880	2260	1010	1700	1320	780
Compressive Strength, 7 days psi	4080	3050	1590	2510	1730	1070
Compressive Strength, 28 days psi	5320	4200	2460	4040	2910	2180
Compressive Strength, 90 days psi	5860	5020	4160	5760	4920	3930
Compressive Strength, 180 days psi	6050	5430	4920	5990	5820	5470
Compressive Strength, 1 year psi		6100	5450		6380	5330
Water - Cement Ratio	0.485	0.485	0.485	0.485	0.485	0.485
Flow %	111	111	110	122	118	106

Pozzolanic Activity Index, ASTM C618

With Lime @ 7 days PSI 1030

With Portland Cement (RC-688) at 28 days percent of Control 88

Test for Pozzolan Hydraulic Activity

Compressive Strength (PSI)

W/C	3days	7days	28days
0.433	30	fell apart	test discontinued

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180	REPORT OF TESTS ON POZZOLAN	Report No: Admixture No: AD 507 Date:

POZZOLAN CLASS: F		DESCRIPTION: Subbituminous Fly Ash	
COMPANY: Union Electric Co.		LOCATION: St. Louis, MO	
MEMO NO: 1985	DATE: 10/6/75	JOB NO: 545-C-530	
MEMO SUBJECT: Variations in Cementitious Media			

CHEMICAL COMPOSITION

SiO_2 %	44.87	Moisture Content %	0.28	Cr_2O_3 %	
Al_2O_3 %	21.83	LOI, % (750°C)	5.69	Chloride %	
Fe_2O_3 %	17.20	LOI, % (1000°C)			
MgO %	0.67	TiO_2 %			
SO_3 %	1.12	P_2O_5 %			
CaO %	4.77	Mn_2O_3 %			

Alkalies	Water Soluble	Available (C-618)	Acid Soluble	Total Alkali
Na_2O %	0.14	0.50	0.34	1.38
K_2O %	0.03	0.78	0.30	2.18
Total as Na_2O %	0.16	1.01	0.54	2.81

PHYSICAL TESTS

Specific Gravity: 2.37 | Fineness: % retained on 325 Sieve

Surface Area: 7660 sqcm/cc, porosity e= 0.480

Tests with portland cement cured @ 73.4 ± 3° F

Portland Cement Co.:	United			Citadel		
Location:	Artesia, MS			Birmingham, AL		
Research Cement No & Type:	RC-688, I, LA			RC-705, II, LA, HH		
Autoclave Expansion, 20% Replacement, %	0.01			0.05		
% Replace of Cement by Volume	0	30	60	0	30	60
Heat of Hydration, 7 days, Cal/gm	84.8	70.5	48.2	67.7	57	41
Heat of Hydration, 28 days, Cal/gm	96.5	83.4	64.5	78.8	66	48
Compressive Strength, 3 days psi	2880	1910	830	1700	1320	690
Compressive Strength, 7 days psi	4080	2600	1110	2510	1660	830
Compressive Strength, 28 days psi	5320	3700	1720	4040	2640	1560
Compressive Strength, 90 days psi	5860	5320	3040	5760	4720	3590
Compressive Strength, 180 days psi	6050	5820	3460	5990	5460	4240
Compressive Strength, 1 year psi		6460	4520		6090	4820
Water - Cement Ratio	0.485	0.485	0.485	0.485	0.485	0.485
Flow %	111	65	62	122	78	60

Pozzolanic Activity Index, ASTM C618
With Lime @ 7 days PSI 1080
With Portland Cement (RC-688) at 28 days percent of Control 80

Test for Pozzolan Hydraulic Activity

Compressive Strength (PSI)

W/C	3days	7days	28days
0.583	to soft to test		

W. G. MILLER
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Chief, Cement & Pozzolan Test Branch

Structures Laboratory
USAE Waterways Exp St
ATTN: Cen & Pozz Test Br
P. O. Box 631
Vicksburg, MS 39180

REPORT OF TESTS ON POZZOLAN

Report No:

Admixture No: AD 509

Date:

POZZOLAN CLASS: F	DESCRIPTION: Lignite Fly Ash
COMPANY: Basin Elec. PWR	LOCATION: Stanton, N.D.
[illegible] NO: 1935	DATE: 10/6/75 — JOB NO: 545-C-530
[illegible] SUBJECT: Variations in Cementitious Media	

CHEMICAL COMPOSITION

SiO_2 %	49.7	Moisture Content %	0.14	Cr_2O_3 %	
Al_2O_3 %	17.78	LOI, % (750°C)	0.20	Chloride %	
Fe_2O_3 %	6.29	LOI, % (1000°C)			
MgO %	4.86	TiO_2 %			
SO_3 %	1.09	P_2O_5 %			
CaO %	13.1	Mn_2O_3 %			

Alkalies	Water Soluble	Available (C-618)	Acid Soluble	Total Alkali
Na_2O %	0.38	1.38	1.31	4.00
K_2O %	0.01	0.38	0.57	1.76
Total as Na_2O %	0.39	1.63	1.69	5.16

PHYSICAL TESTS

Specific Gravity: 2.39 | Fineness: % retained on 325 Sieve

Surface Area: 4690 sqcm/cc, porosity e= 0.387

Tests with portland cement cured @ 73.4 ± 3° F

Portland Cement Co.:	United			Citadel		
Location:	Artesia, MS			Birmingham, AL		
Research Cement No & Type:	RC-688, I, LA			RC-705, II, LA, HH		
Autoclave Expansion, 20% Replacement, %	0.03			0.09		
% Replace of Cement by Volume	0	30	60	0	30	60
Heat of Hydration, 7 days, Cal/gm	84.8	72	51	67.7	52	49
Heat of Hydration, 28 days, Cal/gm	96.5	82	66	78.8	62	56
Compressive Strength, 3 days psi	2890	1880	920	1700	1150	640
Compressive Strength, 7 days psi	4080	2530	1200	2510	1540	820
Compressive Strength, 28 days psi	5320	3620	1810	4040	2640	1520
Compressive Strength, 90 days psi	5860	4460	3090	5760	4140	2750
Compressive Strength, 180 days psi	6050	5000	3470	5990	4750	3200
Compressive Strength, 1 year psi		5320	3980		5310	3520
Water - Cement Ratio	0.485	0.485	0.485	0.485	0.485	0.485
Flow %	111	93	74	122	105	79

Pozzolanic Activity Index, ASTM C618
With Lime @ 7 days PSI 1160
With Portland Cement (RC-688) at 28 days percent of Control 76

Test for Pozzolan Hydraulic Activity

Compressive Strength (PSI)

W/C	3days	7days	28days
0.477	to soft to test		

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180	REPORT OF TESTS ON POZZOLAN	Report No: Admixture No: AD 510 Date:

POZZOLAN CLASS: C	DESCRIPTION: Lignite Fly Ash
COMPANY: Ottertail Power	LOCATION: Fergus Falls, MN
MEMO NO: 1985 DATE: 10/6/75	JOB NO: 545-C-530
MEMO SUBJECT: Variations in Cementitious Media	

CHEMICAL COMPOSITION

SiO_2 %	23.48	Moisture Content %	0.29	Cr_2O_3 %	
Al_2O_3 %	16.36	LOI, % (750°C)	1.14	Chloride %	
Fe_2O_3 %	9.08	LOI, % (1000°C)			
MgO %	8.43	TiO_2 %			
SO_3 %	5.31	P_2O_5 %			
CaO %	29.94	Mn_2O_3 %			

Alkalies	Water Soluble	Available (C-618)	Acid Soluble	Total Alkali
Na_2O %	0.63	2.40	2.51	3.28
K_2O %	0.05	0.23	0.25	0.39
Total as Na_2O %	0.66	2.55	2.67	3.54

PHYSICAL TESTS

Specific Gravity: 2.75 | Fineness: % retained on 325 Sieve

Surface Area: 8750 sqcm/cc, porosity e= 0.460

Tests with portland cement cured @ 73.4 ± 3° F

Portland Cement Co.:	United			Citadel		
Location:	Artesia, MS			Birmingham, AL		
Research Cement No & Type:	RC-688, I, LA			RC-705, II, LA, HH		
Autoclave Expansion, 20% Replacement, %	0.12			0.32		
% Replace of Cement by Volume	0	30	60	0	30	60
Heat of Hydration, 7 days, Cal/gm	84.8	82	73	67.7	67	69
Heat of Hydration, 28 days, Cal/gm	96.5	90	81	78.8	76	77
Compressive Strength, 3 days psi	2880	2710	2380	1700	1990	1440
Compressive Strength, 7 days psi	4080	3650	3030	2510	2530	1800
Compressive Strength, 28 days psi	5320	4920	4090	4040	3730	2950
Compressive Strength, 90 days psi	5860	5460	4970	5760	5270	4600
Compressive Strength, 180 days psi	6050	6260	5250	5990	5320	5120
Compressive Strength, 1 year psi		5840	5740		5610	5220
Water - Cement Ratio	0.485	0.485	0.485	0.485	0.485	0.485
Flow %	111	114	73	122	111	107

Pozzolanic Activity Index, ASTM C618
With Lime @ 7 days PSI 1500
With Portland Cement (RC-688) at 28 days percent of Control 85

Test for Pozzolan Hydraulic Activity

Compressive Strength (PSI)

W/C	3days	7days	28days
0.450	1340	1950	2860

W. G. MILLER
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Chief, Cement & Pozzolan Test Branch

Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180	REPORT OF TESTS ON POZZOLAN	Report No: Admixture No: AD 511 Date:

POZZOLAN CLASS: F	DESCRIPTION: Bituminous Fly Ash	
COMPANY: Amax	LOCATION: Stilesboro, GA (Plant Bowen)	
MEMO NO: 1985	DATE: 10/6/75	JOB NO: 545-C-530
MEMO SUBJECT: Variations in Cementitious Media		

CHEMICAL COMPOSITION

SiO_2 %	45.4	Moisture Content %	0.31	Cr_2O_3 %	
Al_2O_3 %	24.34	LOI, % (750°C)	4.26	Chloride %	
Fe_2O_3 %	15.02	LOI, % (1000°C)			
MgO %	1.12	TiO_2 %			
SO_3 %	0.73	P_2O_5 %			
CaO %	2.69	Mn_2O_3 %			

Alkalies	Water Soluble	Available (C-618)	Acid Soluble	Total Alkali
Na_2O %	0.02	0.14	0.06	0.38
K_2O %	0.03	0.88	0.36	2.61
Total as Na_2O %	0.04	0.72	0.30	2.10

PHYSICAL TESTS

Specific Gravity: 2.45 | Fineness: % retained on 325 Sieve

Surface Area: 6870 sqcm/cc, porosity e= 0.463

Tests with portland cement cured @ 73.4 ± 3° F

Portland Cement Co.:	United			Citadel		
Location:	Artesia, MS			Birmingham, AL		
Research Cement No & Type:	RC-688, I, LA			RC-705, II, LA, HH		
Autoclave Expansion, 20% Replacement, %	0.00			0.04		
% Replace of Cement by Volume	0	30	60	0	30	60
Heat of Hydration, 7 days, Cal/gm	84.8	68	47	67.7	55	39
Heat of Hydration, 28 days, Cal/gm	96.5	83	62	78.8	68	45
Compressive Strength, 3 days psi	2880	1900	880	1700	1200	620
Compressive Strength, 7 days psi	4080	2650	1180	2510	1560	760
Compressive Strength, 28 days psi	5320	3830	1790	4040	2600	1420
Compressive Strength, 90 days psi	5860	5390	3040	5760	4850	2740
Compressive Strength, 180 days psi	6050	5870	3750	5990	5480	3670
Compressive Strength, 1 year psi		5140	4870		6400	4260
Water - Cement Ratio	0.485	0.485	0.485	0.485	0.485	0.485
Flow %	111	90	74	122	96	79

Pozzolanic Activity Index, ASTM C618
With Lime @ 7 days PSI 1020
With Portland Cement (RC-688) at 28 days percent of Control 91

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180	REPORT OF TESTS ON POZZOLAN	Report No: Admixture No: AD 512 Date:

POZZOLAN CLASS: F	DESCRIPTION: Subbituminous Fly Ash	
COMPANY: Iowa Public Service	LOCATION: Sioux City, IA	
MEMO NO: 1985	DATE: 10/6/75	JOB NO: 545-C-530
MEMO SUBJECT: Variations in Cementitious Media		

CHEMICAL COMPOSITION

SiO_2 %	43.28	Moisture Content %	0.21	Cr_2O_3 %	
Al_2O_3 %	19.71	LOI, % (750°C)	1.14	Chloride %	
Fe_2O_3 %	7.68	LOI, % (1000°C)			
MgO %	3.34	TiO_2 %			
SO_3 %	1.75	P_2O_5 %			
CaO %	20.32	Mn_2O_3 %			

Alkalies	Water Soluble	Available (C-618)	Acid Soluble	Total Alkali
Na_2O %	0.00	0.23	0.13	0.45
K_2O %	0.00	0.77	0.29	1.54
Total as Na_2O %	0.00	0.74	0.32	1.46

PHYSICAL TESTS

Specific Gravity: 2.58	Fineness: % retained on 325 Sieve
Surface Area: 12830	sqcm/cc, porosity e= 0.458

Tests with portland cement cured @ 73.4 ± 3° F

Portland Cement Co.:	United			Citadel		
Location:	Artesia, MS			Birmingham, AL		
Research Cement No & Type:	RC-688, I, LA			RC-705, II, LA, HH		
Autoclave Expansion, 20% Replacement, %	0.08			0.14		
% Replace of Cement by Volume	0	30	60	0	30	60
Heat of Hydration, 7 days, Cal/gm	84.8	74	52	67.7	63	43
Heat of Hydration, 28 days, Cal/gm	96.5	86	73	78.8	72	63
Compressive Strength, 3 days psi	2880	2330	1130	1700	1430	760
Compressive Strength, 7 days psi	4080	3190	1630	2510	2040	1170
Compressive Strength, 28 days psi	5320	4760	2560	4040	3680	1840
Compressive Strength, 90 days psi	5860	6360	5030	5760	6000	4040
Compressive Strength, 180 days psi	6050	7450	5220	5990	7395	5950
Compressive Strength, 1 year psi		7810	7000		6900	
Water - Cement Ratio	0.485	0.465	0.485	0.485	0.461	0.485
Flow %	111	114	138	122	120	139

Pozzolanic Activity Index, ASTM C618
With Lime @ 7 days PSI 1750
With Portland Cement (RC-688) at 28 days percent of Control 111

Test for Pozzolan Hydraulic Activity

Compressive Strength (PSI)

W/C	3days	7days	28days
0.400	75	20	fell apart

W. G. MILLER
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Chief, Cement & Pozzolan Test Branch

Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180	REPORT OF TESTS ON POZZOLAN	Report No: Admixture No: AD 513 Date:

POZZOLAN CLASS: C	DESCRIPTION: Lignite Fly Ash
COMPANY: Colorado Public Serv	LOCATION: Pueblo, CO. (Comanche Plant)
MEMO NO: 1955	DATE: 10/6/75 JOB NO: 545-C-530
MEMO SUBJECT: Variations in Cementitious Media	

CHEMICAL COMPOSITION

SiO_2 %	38.12	Moisture Content %	0.14	Cr_2O_3 %	
Al_2O_3 %	25.68	LOI, % (750°C)	0.14	Chloride %	
Fe_2O_3 %	4.65	LOI, % (1000°C)			
MgO %	4.42	TiO_2 %			
SO_3 %	1.55	P_2O_5 %			
CaO %	21.01	Mn_2O_3 %			

Alkalies	Water Soluble	Available (C-618)	Acid Soluble	Total Alkali
Na_2O %	0.01	0.47	0.67	1.30
K_2O %	0.00	0.28	0.28	0.58
Total as Na_2O %	0.01	0.65	0.85	1.65

PHYSICAL TESTS

Specific Gravity: 2.61	Fineness: % retained on 325 Sieve
Surface Area: 12,790	sqcm/cc, porosity e= 0.475

Tests with portland cement cured @ 73.4 ± 3° F

Portland Cement Co.:	United			Citadel		
Location:	Artesia, MS			Birmingham, AL		
Research Cement No & Type:	RC-688, I, LA			RC-705, II, LA, HH		
Autoclave Expansion, 20% Replacement, %	0.01			0.08		
% Replace of Cement by Volume	0	30	60	0	30	60
Heat of Hydration, 7 days, Cal/gm	84.8	80	51	67.7	63	27
Heat of Hydration, 28 days, Cal/gm	96.5	93	79	78.8	78	50
Compressive Strength, 3 days psi	2380	2200	880	1700	1240	30
Compressive Strength, 7 days psi	4080	3300	1650	2510	2120	120
Compressive Strength, 28 days psi	5320	4900	2740	4040	3620	1780
Compressive Strength, 90 days psi	5860	7010	4680	5760	6690	3520
Compressive Strength, 180 days psi	6050	7180	5660	5990	7120	
Compressive Strength, 1 year psi		7210	6280		7680	
Water - Cement Ratio	0.485	0.464	0.485	0.485	0.460	0.485
Flow %	111	108	134	122	118	136

Pozzolanic Activity Index, ASTM C618
With Lime @ 7 days PSI 1270
With Portland Cement (RC-688) at 28 days percent of Control 111

<u>Tests for Pozzolan Hydraulic Activity</u>

Compressive Strength (PSI)

W/C	3days	7days	28days
0.410	50	120	360

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Chief, Cement & Pozzolan Test Branch

Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180	REPORT OF TESTS ON POZZOLAN	Report No: Admixture No: AD 515 Date:

POZZOLAN CLASS: N — DESCRIPTION: Natural
COMPANY: Oregon PC Co. — LOCATION: Lime, OR
MEMO NO: 1985 — DATE: 10/6/75 — JOB NO: 545-C-530
MEMO SUBJECT: Variations in Cementitious Media

CHEMICAL COMPOSITION

SiO_2 %	53.0	Moisture Content %		Cr_2O_3 %	
Al_2O_3 %	16.71	LOI, % (750°C)	1.27	Chloride %	
FeO_3 %	7.06	LOI, % (1000°C)			
MgO %	3.43	TiO_2 %			
SO_3 %	0.17	P_2O_5 %			
CaO %	7.97	Mn_2O_3 %			

Alkalies	Water Soluble	Available (C-618)	Acid Soluble	Total Alkali
Na_2O %		0.70	0.39	1.82
K_2O %		0.76	0.14	3.48
Total as Na_2O %		1.20	0.48	4.11

PHYSICAL TESTS

Specific Gravity: 2.76 — Fineness: % retained on 325 Sieve
Surface Area: 18,060 sqcm/cc, porosity e= 0.504
Tests with portland cement cured @ 73.4 ± 3° F

Portland Cement Co.:	United			Citadel		
Location:	Artesia, MS			Birmingham, AL		
Research Cement No & Type:	RC-688, I, LA			RC-705, II, LA, HH		
Autoclave Expansion, 20% Replacement, %						
% Replace of Cement by Volume	0	30	60	0	30	60
Heat of Hydration, 7 days, Cal/gm	84.8			67.7		
Heat of Hydration, 28 days, Cal/gm	96.5			78.8		
Compressive Strength, 3 days psi	2380	2000	1050	1700	1120	730
Compressive Strength, 7 days psi	4080	2830	1500	2510	1550	1000
Compressive Strength, 28 days psi	5320	4180	2510	4040	3040	2180
Compressive Strength, 90 days psi	5860			5760		
Compressive Strength, 180 days psi	6050			5990		
Compressive Strength, 1 year psi						
Water - Cement Ratio	0.485	0.485	0.485	0.485	0.485	0.485
Flow %	111	102	92	122	118	84

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180	REPORT OF TESTS ON POZZOLAN	Report No: Admixture No: AD 516 Date:

POZZOLAN CLASS: N		DESCRIPTION: Santorin Earth, Santorin, Greece	
COMPANY: Dundee		LOCATION: Dundee, MI	
MEMO NO: 1985	DATE: 10/6/75	JOB NO: 545-C-530	
MEMO SUBJECT: Variations in Cementitious Media			

CHEMICAL COMPOSITION

SiO_2 %	60.49	Moisture Content %	0.20	Cr_2O_3 %	
Al_2O_3 %	13.34	LOI, % (750°C)	3.80	Chloride %	
Fe_2O_3 %	3.99	LOI, % (1000°C)			
MgO %	1.12	TiO_2 %	0.08		
SO_3 %	0.34	P_2O_5 %			
CaO %	6.68	Mn_2O_3 %			

Alkalies	Water Soluble	Available (C-618)	Acid Soluble	Total Alkali
Na_2O %		0.92	0.40	4.27
K_2O %		0.74	0.15	2.77
Total as Na_2O %		1.41	0.50	6.09

PHYSICAL TESTS

Specific Gravity: 2.49 | Fineness: % retained on 325 Sieve

Surface Area: 15,000 sqcm/cc, porosity e= 0.553

Tests with portland cement cured @ 73.4 ± 3° F

Portland Cement Co.:	United			Citadel		
Location:	Artesia, MS			Birmingham, AL		
Research Cement No & Type:	RC-688, I, LA			RC-705, II, LA, HH		
Autoclave Expansion, 20% Replacement, %						
% Replace of Cement by Volume	0	30	60	0	30	60
Heat of Hydration, 7 days, Cal/gm	84.8			67.7		
Heat of Hydration, 28 days, Cal/gm	96.5			78.8		
Compressive Strength, 3 days psi	2880			1700		
Compressive Strength, 7 days psi	4080			2510		
Compressive Strength, 28 days psi	5320			4040		
Compressive Strength, 90 days psi	5860			5760		
Compressive Strength, 180 days psi	6050			5990		
Compressive Strength, 1 year psi						
Water - Cement Ratio	0.485			0.485		
Flow %	111			122		

Oxide Composition determined by AA

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180	REPORT OF TESTS ON POZZOLAN	Report No: Admixture No: AD 517 Date:

POZZOLAN CLASS: F | DESCRIPTION: Fly Ash

COMPANY: Detroit Edison | LOCATION: Trenton Power Plant (submitted by Dundee)

MEMO NO: 1985 | DATE: 10/6/75 | JOB NO: 545-C-530

MEMO SUBJECT: Variations in Cementitious Media

CHEMICAL COMPOSITION

SiO_2 %	49.63	Moisture Content %	0.09	Cr_2O_3 %	
Al_2O_3 %	26.16	LOI, % (750°C)	2.96	Chloride %	
Fe_2O_3 %	12.37	LOI, % (1000°C)			
MgO %	0.73	TiO_2 %	0.25		
SO_3 %	0.49	P_2O_5 %			
CaO %	1.44	Mn_2O_3 %			

Alkalies	Water Soluble	Available (C-618)	Acid Soluble	Total Alkali
Na_2O %		0.07	0.05	0.26
K_2O %		0.61	0.30	2.38
Total as Na_2O %		0.47	0.25	1.83

PHYSICAL TESTS

Specific Gravity: 2.32 | Fineness: % retained on 325 Sieve

Surface Area: 6520 sqcm/cc, porosity e= 0.504

Tests with portland cement cured @ 73.4 ± 3° F

Portland Cement Co.:	United			Citadel		
Location:	Artesia, MS			Birmingham, AL		
Research Cement No & Type:	RC-688, I, LA			RC-705, II, LA, HH		
Autoclave Expansion, 20% Replacement, %						
% Replace of Cement by Volume	0	30	60	0	30	60
Heat of Hydration, 7 days, Cal/gm	84.8			67.7		
Heat of Hydration, 28 days, Cal/gm	96.5			78.8		
Compressive Strength, 3 days psi	2880			1700		
Compressive Strength, 7 days psi	4080			2510		
Compressive Strength, 28 days psi	5320			4040		
Compressive Strength, 90 days psi	5860			5760		
Compressive Strength, 180 days psi	6050			5990		
Compressive Strength, 1 year psi						
Water - Cement Ratio	0.485			0.485		
Flow %	111			122		

Oxides determined by AA

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180	REPORT OF TESTS ON POZZOLAN	Report No: Admixture No: AD 518 Date:

POZZOLAN CLASS: N	DESCRIPTION: Natural		
COMPANY: Superior Prod	LOCATION: Hallelujah Junction, CA		
MEMO NO: 1985	DATE: 10/6/75	JOB NO: 545-C-530	
MEMO SUBJECT: Variations in Cementitious Media			

CHEMICAL COMPOSITION

SiO_2 %	67.98	Moisture Content %	1.37	Cr_2O_3 %	
Al_2O_3 %	17.40	LOI, % (750°C)	1.58	Chloride %	
Fe_2O_3 %	5.49	LOI, % (1000°C)			
MgO %	0.80	TiO_2 %			
SO_3 %	0.88	P_2O_5 %			
CaO %	2.28	Mn_2O_3 %			

Alkalies	Water Soluble	Available (C-618)	Acid Soluble	Total Alkali
Na_2O %	0.02	0.18	0.16	2.11
K_2O %	0.00	0.26	0.19	1.59
Total as Na_2O %	0.02	0.35	0.28	3.16

PHYSICAL TESTS

Specific Gravity: 2.39 | Fineness: % retained on 325 Sieve

Surface Area: 26,760 sqcm/cc, porosity e= 0.668

Tests with portland cement cured @ 73.4 ± 3° F

Portland Cement Co.:	United			Citadel		
Location:	Artesia, MS			Birmingham, AL		
Research Cement No & Type:	RC-688, I, LA			RC-705, II, LA, HH		
Autoclave Expansion, 20% Replacement, %	0.03			0.06		
% Replace of Cement by Volume	0	30	60	0	30	60
Heat of Hydration, 7 days, Cal/gm	84.8	75	59	67.7	60	46
Heat of Hydration, 28 days, Cal/gm	96.5	86	68	78.8	72	61
Compressive Strength, 3 days psi	2880	2710	1120	1700	1710	920
Compressive Strength, 7 days psi	4080	3920	1880	2510	2480	1480
Compressive Strength, 28 days psi	5320	6050	4010	4040	4930	3640
Compressive Strength, 90 days psi	5860	6780	6350	5760	5540	4860
Compressive Strength, 180 days psi	6050	7330	7240	5990	5620	5380
Compressive Strength, 1 year psi		7690	7250		5880	5460
Water - Cement Ratio	0.485	0.485	0.532	0.485	0.485	0.532
Flow %	111	51	40	122	62	62

Pozzolanic Activity Index, ASTM C618
With Lime @ 7 days PSI 1960
With Portland Cement (RC-688) at 28 days percent of Control 98

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180	REPORT OF TESTS ON POZZOLAN	Report No: Admixture No: AD 536 Date:

POZZOLAN CLASS:	DESCRIPTION: Amorphous Silica Spheres	
COMPANY: Reynolds Aluminum	LOCATION: Sheffield, AL	
MEMO NO: 1985	DATE: 10/6/75	JOB NO: 545-C-530
MEMO SUBJECT: Variations in Cementitious Media		

CHEMICAL COMPOSITION

SiO_2 %	95.98	Moisture Content %	0.27	Cr_2O_3 %	
Al_2O_3 %	1.26	LOI, % (750°C)	1.13	Chloride %	
Fe_2O_3 %	0.12	LOI, % (1000°C)			
MgO %	0.03	TiO_2 %			
SO_3 %	0.12	P_2O_5 %			
CaO %	0.26	Mn_2O_3 %			

Alkalies %	Water Soluble	Available (C-618)	Acid Soluble	Total Alkali
Na_2O %		0.06	0.03	0.15
K_2O %		0.03	0.00	0.24
Total as Na_2O%		0.08	0.03	0.31

PHYSICAL TESTS

Specific Gravity: 2.22	Fineness % retained on 325 Sieve
Surface Area: 58700 sqcm/cc, porosity e =	
Tests with portland cement cured @ 73.4 ± 3°F	

Portland Cement Co:	United			Citadel		
Location:	Artesia, MS			Birmingham, AL		
Research Cement No & Type:	RC-688 I, LA			RC-705, II, LA, HH		
Autoclave Expansion, 20% Replacement, %						
% Replace of Cement by Volume	0	30	60	0	30	60
Heat of Hydration, 7 days, Cal/gm	84.8	73	56	67.7	61	52
Heat of Hydration, 28 days, Cal/gm	96.5	90	78	78.8	74	58
Compressive Strength, 3 days psi	2880	1280*		1700		
Compressive Strength, 7 days psi	4080	4180		2510		
Compressive Strength, 28 days psi	5320	6860		4040		
Compressive Strength, 90 days psi	5860			5760		
Compressive Strength, 180 days psi	6050			5990		
Compressive Strength, 365 days psi						
Water - Cement Ratio	0.485			0.485		
Flow	111			122		

* 1 day strength

Lime Pozzolan strength, 360 Ml H_2O, Flow 99% 1170 PSI

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Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180	REPORT OF TESTS ON POZZOLAN	Report No: Admixture No: AD536(2) Date:

POZZOLAN CLASS:	DESCRIPTION: Amorphous Silica Spheres	
COMPANY: Reynolds Aluminum	LOCATION: Sheffield, AL	
MEMO NO: 1985	DATE: 10/6/75	JOB NO: 545-C-530
MEMO SUBJECT: Variations in Cementitious Media		

CHEMICAL COMPOSITION

SiO_2 %	93.90	Moisture Content %	0.38	Cr_2O_3 %	0.00
Al_2O_3 %	0.70	LOI, % (750°C)	0.99	Chloride %	0.01
Fe_2O_3 %	0.00	LOI, % (1000°C)	1.16		
MgO %	1.20	TiO_2 %			
SO_3 %	0.20	P_2O_5 %			
CaO %	0.78	Mn_2O_3 %	0.00		

Alkalies %	Water Soluble	Available (C-618)	Acid Soluble	Total Alkali
Na_2O %		0.03		0.15
K_2O %		0.04		0.24
Total as Na_2O%		0.07		0.31

PHYSICAL TESTS

Specific Gravity: 2.22 | Fineness % retained on 325 Sieve

Surface Area: 98,900 sqcm/cc, porosity e = 0.714

Tests with portland cement cured @ 73.4 ± 3°F

Portland Cement Co:	United			Citadel		
Location:	Artesia, MS			Birmingham, AL		
Research Cement No & Type:	RC-688(3) I, LA			RC-705, II, LA, HH		
Autoclave Expansion, 20% Replacement, %						
% Replace of Cement by Volume	0	30	60	0	30	60
Heat of Hydration, 7 days, Cal/gm						
Heat of Hydration, 28 days, Cal/gm						
Compressive Strength, 3 days psi	3710*	2430	640	1700	1160	450
Compressive Strength, 7 days psi	4390	3890	1750	2510	2950	2120
Compressive Strength, 28 days psi	6030	7030	4210	4040	5480	3650
Compressive Strength, 90 days psi	6550	8870	4890	5760	6740	4030
Compressive Strength, 180 days psi	7230	8990	5360	5990	6820	4580
Compressive Strength, 365 days psi	6790	8880	5540		6600	4330
Water - Cement Ratio		0.546	0.782		0.546	0.782
Flow		64	48		86	72

Lime-Pozzolan Strength cured 24 hrs @ 73.4 ± 3°F, 6 d ys @ 130 ± 3°F: 1870 psi 200gm pozz + 100 gm lime & 375ml H_2O, Flow 88.

Pozzolanic Activity Index, ASTM C618
With Portland Cement (RC-688) at 28 days percent of Control 145

W. G. MILLER
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Chief, Cement & Pozzolan Test Branch

*CORRECTED COPY

LABORATORY: Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Group P.O. Box 631 Vicksburg, MS 39180	REPORT OF TESTS ON POZZOLAN SS-C-1960/5 AD-536(3)	REPORT NO.: WES-178-80 SHEET 1 OF 1 DATE: 29 May 80

CLASS F N	Silica Fume
SOURCE: Reynolds Metal Co., Listerhill, AL	BRAND:
TEST RESULTS OF THIS SAMPLE LOT ☐ COMPLY ☐ DO NOT COMPLY WITH SPECIFICATION LIMITS (SEE REMARKS)	
FOR USE AT:	
CONTRACT NO.:	
DISTRICT(S):	
SAMPLED BY:	DATE SAMPLED:
CAR NO.:	BIN NO.:
FIELD SAMPLE NO.:	LAB SAMPLE NO.:
DATE RECEIVED: 23 April 80	LAB JOB NO.:
TESTED BY: Cement & Pozzolan Group	CHECKED BY:

TESTS ON COMPOSITE OF THE 100-TON SAMPLES LISTED BELOW

$SiO_2 + Al_2O_3 + Fe_2O_3$ %	MgO %	SO_3 %	AVAILABLE ALKALIES %	POZZOLAN STRENGTH % CONTROL	INCREASE IN SHRINKAGE % (a)	AUTOCLAVE EXPANSION %	REDUCTION IN EXPANSION % (b)
REQUIREMENTS							
MIN 70.0	MAX 5.0	MAX 4.0	MAX 1.50	MIN 75	MAX 0.03	MAX 0.50	MIN 75
TEST RESULTS							
97.7	0.2	0.3	0.10	140		-0.06	

TESTS ON SAMPLES REPRESENTING 100 TONS OR LESS

SAMPLE NO.	MOISTURE CONTENT %	LOSS ON IGNITION %	Fineness 325 Mesh Sieve % Retained	% pts var from avg prev 10	LIME POZZOLAN STRENGTH PSI	WATER REQUIREMENT % of Control	SPECIFIC GRAVITY	SP GR VARIATION FROM AVERAGE OF PRECEDING 10, %
REQUIREMENTS								
—	MAX 3.0	MAX 10.0 (N) 6.0 (F)	MAX 34	MAX 5	MIN 900	MAX 105	—	MAX 5
TEST RESULTS								
1	0.2	0.7	0.42		2050		2.22	
Air Permeability Fineness			42550 Sq CM/CC					
			(porosity e=0.714)					
SiO2	96.6		Total Alkali by		LiBO2 fusion			
Al2O3	1.0		Na2		0.22			
Fe2O3	0.1		K2O		0.43			
			Total as	Na2O	0.50			
AVERAGE	—	—		—	—	—		—

(a) APPLICABLE ONLY TO CLASS N
(b) OPTIONAL REQUIREMENT

LABORATORY CEMENT USED RC-688
LABORATORY LIME USED Chemstone

REMARKS:

NOTE: Pozzolanic Strength
Control W/C 0.484, flow 114%
Test mix W/C 0.528, flow 64%

W. G. Miller
W. G. MILLER
Chemist
Chief, Cement & Pozzolan Group

NOTE: THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U. S. GOVERNMENT.

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Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180	REPORT OF TESTS ON POZZOLAN	Report No: WES-211S-82 Admixture No: AD 536(4) Date: 24 June 82

POZZOLAN CLASS:	DESCRIPTION: silica Fume		
COMPANY: Reynolds Metals Co	LOCATION: Richmond, VA (See(1)below)		
MEMO NO:	DATE:	JOB NO:	441-S866.12SC51
MEMO SUBJECT:			

CHEMICAL COMPOSITION

SiO_2 %	95.80	Moisture Content %	0.30	Cr_2O_3 %	
Al_2O_3 %	1.11	LOI, % (750°C)	1.27	Chloride %	
Fe_2O_3 %	0.11	LOI, % (1000°C)			
MgO %	0.06	TiO_2 %			
SO_3 %	0.11	P_2O_5 %			
CaO %	0.24	Mn_2O_3 %			

Alkalies	Water Soluble	Available (C-618)	Acid Soluble	Total Alkali
Na_2O %				
K_2O %				
Total as Na_2O %				

PHYSICAL TESTS

Specific Gravity: 2.21 | Fineness: 14 % retained on 325 Sieve

Surface Area: 21000 sqcm/cc, porosity e= 0.720 (see(2)below)

Tests with portland cement cured @ 73.4 ± 3° F

Portland Cement Co.: Medusa

Location: Clinchfield, GA

Cement No & Type: SAS-423-82, II, LA, HH

Autoclave Expansion, 20% Replacement, % 0.00

% Replacement of Cement by Volume	0	30	60	0	35	% of
Heat of Hydration, 7 days, Cal/gm				Control		Control
Heat of Hydration, 28 days, Cal/gm						
Compressive Strength, 7 days, psi	(Lime-Pozzolan ASTM C-311D)			1840		
Compressive Strength, 28 days, psi	(cured @ 100°F)			5340	6350	118
Compressive Strength, days, psi	Water Requirement, % of Control: 123					
Compressive Strength, 90 days, psi						
Compressive Strength, 180 days, psi						
Compressive Strength, 1 year, psi						
Water - Cement Ratio						
Flow %						

(1) Reynolds Chemicals Amorphous Silica, RS-1 (6-50 lbs. bags)Sheffield, Alabama Plant.

(2) e=0.703, SA 34900 cm^2/cc
e=0.710, SA 30400 cm^2/cc

R E Reinhold

R. E. REINHOLD
Chief, Cement & Pozzolan Test Branch

Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180	REPORT OF TESTS ON POZZOLAN	Report No: Admixture No: AD 537 Date:

POZZOLAN CLASS:	DESCRIPTION: Slag	
COMPANY: Wyandotte Cement	LOCATION: Wyandotte, MI	
MEMO NO: 1985	DATE: 10/6/75	JOB NO: 545-C-530
MEMO SUBJECT: Variations in Cementitious Media		

CHEMICAL COMPOSITION

SiO_2 %	38.65	Moisture Content %		Cr_2O_3 %	
Al_2O_3 %	9.04	LOI, % (750 C)	2.28	Chloride %	
Fe_2O_3 %	0.40	LOI, % (1000 C)		Insol. Resideue, %	0.71
MgO %	14.78	TiO_2 %			
SO_3 %	0.03	P_2O_5 %			
CaO %	33.47	Mn_2O_3 %			

Alkalies %	Water Soluble	Available (C-618)	Acid Soluble	Total Alkali
Na_2O %	0.01	0.06	0.27	
K_2O %	0.01	0.14	0.40	
Total as Na_2O%	0.02	0.15	0.53	

PHYSICAL TESTS

Specific Gravity: | Fineness | % retained on 325 Sieve

Surface Area: sqcm/cc, porosity e =

Tests with portland cement cured @ 73.4 ± 3 F

Portland Cement Co:						
Location:						
Research Cement No & Type:						
Autoclave Expansion, 20% Replacement, %						
% Replace of Cement by Volume	0	30	60	0	30	60
Heat of Hydration, 7 days, Cal/gm						
Heat of Hydration, 28 days, Cal/gm						
Compressive Strength, 3 days psi						
Compressive Strength, 7 days psi						
Compressive Strength, 28 days psi						
Compressive Strength, 90 days psi						
Compressive Strength, 180 days psi						
Compressive Strength, 365 days psi						
Water - Cement Ratio						
Flow						

W. G. MILLER
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Chief, Cement & Pozzolan Test Branch

Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180	REPORT OF TESTS ON POZZOLAN	Report No: Admixture No: AD 541 Date:

POZZOLAN CLASS:		DESCRIPTION: Silica Fume	
COMPANY Ohio Ferro-Alloys Corp		LOCATION: Powhaton, Ohio	
MEMO NO: 1985	DATE: 10/6/75	JOB NO: 545-C-530	
MEMO SUBJECT: Variations in Cementitious Media			

CHEMICAL COMPOSITION

SiO_2 %	95.22	Moisture Content %	0.24	Cr_2O_3 %	0.00
Al_2O_3 %	0.27	LOI, % (750°C)	1.28	Chloride %	0.05
Fe_2O_3 %	0.35	LOI, % (1000°C)	1.68		
MgO %	0.26	TiO_2 %			
SO_3 %	0.06	P_2O_5 %			
CaO %	0.34	Mn_2O_3 %	0.01		

Alkalies %	Water Soluble	Available (C-618)	Acid Soluble	Total Alkali
Na_2O %		0.07	0.05	0.12
K_2O %		0.08	0.12	0.35
Total as Na_2O%		0.12	0.13	0.35

PHYSICAL TESTS

Specific Gravity: 2.21	Fineness	% retained on 325 Sieve
Surface Area: 61,400	sqcm/cc, porosity	e = 0.727

Tests with portland cement cured @ 73.4 ± 3°F

Portland Cement Co:	United					
Location:						
Research Cement No & Type:	RC-688(3)					
Autoclave Expansion, 20% Replacement, %						
% Replace of Cement by Volume	0	30	60	0	30	60
Heat of Hydration, 7 days, Cal/gm						
Heat of Hydration, 28 days, Cal/gm						
Compressive Strength, 3 days psi	2950	1360 *				
Compressive Strength, 7 days psi	4390	3020				
Compressive Strength, 28 days psi	6030	5360				
Compressive Strength, 90 days psi	6550	6680				
Compressive Strength, 180 days psi	7230	7010				
Compressive Strength, 365 days psi	6790	7000				
Water - Cement Ratio	0.485	0.601				
Flow	114	62				

* 2 day comp strength
Lime Pozzolan Compressive Strength, 365 ml H_2O, Flow 84% 1970 psi.

W. G. MILLER
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Chief, Cement & Pozzolan Test Branch

Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180	REPORT OF TESTS ON POZZOLAN	Report No: Admixture No: AD 542 Date:

POZZOLAN CLASS: | DESCRIPTION: Silica Fume
COMPANY: Ohio Ferro Alloys Corp | LOCATION: Philo, Ohio
MEMO NO: 1985 | DATE: 10/6/75 | JOB NO: 545-C-530
MEMO SUBJECT: Variations in Cementitious Media

CHEMICAL COMPOSITION

SiO_2 %	89.35	Moisture Content %	0.38	Cr_2O_3 %	0.00
Al_2O_3 %	0.76	LOI, % (750 C)	3.53	Chloride %	0.17
Fe_2O_3 %	1.46	LOI, % (1000 C)	4.51		
MgO %	1.49	TiO_2 %			
SO_3 %	0.14	P_2O_5 %			
CaO %	0.62	Mn_2O_3 %	0.16		

Alkalies %	Water Soluble	Available (C-618)	Acid Soluble	Total Alkali
Na_2O %		0.14	0.14	0.26
K_2O %		0.16	0.18	0.72
Total as Na_2O%		0.25	C.26	0.73

PHYSICAL TESTS

Specific Gravity: 2.30 | Fineness % retained on 325 Sieve
Surface Area: 85,200 sqcm/cc, porosity e = 0.762
Tests with portland cement cured @ 73.4 ± 3 F

Portland Cement Co:	United Cement			Citadel		
Location:	Artesia, MS			Birmingham, AL		
Research Cement No & Type:	RC-688(3), I, LA			RC-705, II, LA, HH		
Autoclave Expansion, 20% Replacement, %						
% Replace of Cement by Volume	0	30	60	0	30	60
Heat of Hydration, 7 days, Cal/gm						
Heat of Hydration, 28 days, Cal/gm						
Compressive Strength, 3 days psi	2950	2070	490	1700	1370	
Compressive Strength, 7 days psi	4390	3610	1280	2510	2690	
Compressive Strength, 28 days psi	6030	6280	3530	4040	5070	
Compressive Strength, 90 days psi	6550	7100	4270	5760	6320	
Compressive Strength, 180 days psi	7230	7860	4350	5990	6670	
Compressive Strength, 365 days psi	6790	7360	4620		5810	
Water - Cement Ratio	0.485	0.511	0.770	0.485	0.511	
Flow	114	64	67	122	76	

Lime-Pozzolan Strength 385ml H_2O 88% Flow 850 psi

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Chemist
Chief, Cement & Pozzolan Test Branch

Structures Laboratory
USAE Waterways Exp St
ATTN: Cem & Pozz Test Br
P. O. Box 631
Vicksburg, MS 39180

REPORT OF TESTS
ON POZZOLAN

Report No:
Admixture No: AD 543
Date:

POZZOLAN CLASS:
DESCRIPTION: Silica Fume
COMPANY National Mettalurgica
LOCATION: Springfield, OR
MEMO NO: 1985 | DATE: 10/6/75 | JOB NO: 545-C-530
MEMO SUBJECT: Variations in Cementitious Media

CHEMICAL COMPOSITION

SiO_2 %	92.62	Moisture Content %	0.20	Cr_2O_3 %	0.00
Al_2O_3 %	0.62	LOI, % (750 C)	2.71	Chloride %	0.04
FeO_3 %	0.27	LOI, % (1000 C)	3.02		
MgO %	0.23	TiO_2 %			
SO_3 %	0.09	P_2O_5 %			
CaO %	0.32	Mn_2O_3 %	0.01		

Alkalies %	Water Soluble	Available (C-618)	Acid Soluble	Total Alkali
Na_2O %		0.05	0.06	0.13
K_2O %		0.05	0.08	0.32
Total as Na_2O%		0.08	0.11	0.34

PHYSICAL TESTS

Specific Gravity: 2.23 | Fineness % retained on 325 Sieve
Surface Area: 75,200 sqcm/cc, porosity e = 0.779
Tests with portland cement cured @ 73.4 $\pm$ 3 F

Portland Cement Co:						
Location:						
Research Cement No & Type:						
Autoclave Expansion, 20% Replacement, %						
% Replace of Cement by Volume	0	30	60	0	30	60
Heat of Hydration, 7 days, Cal/gm						
Heat of Hydration, 28 days, Cal/gm						
Compressive Strength, 3 days psi						
Compressive Strength, 7 days psi						
Compressive Strength, 28 days psi						
Compressive Strength, 90 days psi						
Compressive Strength, 180 days psi						
Compressive Strength, 365 days psi						
Water - Cement Ratio						
Flow						

Lime-Pozz, Comp Str 385ml H_2O 72% Flow 1720 psi

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180	REPORT OF TESTS ON POZZOLAN	Report No: Admixture No: AD 544(75) Date:

POZZOLAN CLASS:	DESCRIPTION: Silica Fume	
COMPANY: Hanna Mining Co.	LOCATION: Wenatchee, WA	
MEMO NO: 1985	DATE: 10/6/75	JOB NO: 545-C-530
MEMO SUBJECT: Variations in Cementitious Media		

CHEMICAL COMPOSITION

SiO_2 %	90.10	Moisture Content %	0.63	Cr_2O_3 %	0.00
Al_2O_3 %	1.72	LOI, % (750 C)	3.78	Chloride %	0.11
Fe_2O_3 %	1.93	LOI, % (1000 C)	4.64		
MgO %	0.35	TiO_2 %			
SO_3 %	0.07	P_2O_5 %			
CaO %	1.57	Mn_2O_3 %	0.11		

Alkalies %	Water Soluble	Available (C-618)	Acid Soluble	Total Alkali
Na_2O %		0.14	0.10	0.29
K_2O %		0.09	0.13	0.55
Total as Na_2O%		0.20	0.19	0.65

PHYSICAL TESTS

Specific Gravity: 2.28	Fineness	% retained on 325 Sieve
Surface Area: 58,520	sqcm/cc, porosity	e = 0.844

Tests with portland cement cured @ 73.4 ± 3 F

Portland Cement Co:	United					
Location:	Artesia, MS					
Research Cement No & Type:	RC-688(3), I, LA					
Autoclave Expansion, 20% Replacement, %						
% Replace of Cement by Volume	0	30	60	0	30	60
Heat of Hydration, 7 days, Cal/gm						
Heat of Hydration, 28 days, Cal/gm						
Compressive Strength, 3 days psi	2950	2310				
Compressive Strength, 7 days psi	4390	3320				
Compressive Strength, 28 days psi	6030	6360				
Compressive Strength, 90 days psi	6550	6950				
Compressive Strength, 180 days psi	7230	7520				
Compressive Strength, 365 days psi	6790	8140				
Water - Cement Ratio	0.485	0.54				
Flow	114	64				

Lime-Pozz Comp Str 325ml H_2O 63% Flow 2070 psi

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180	REPORT OF TESTS ON POZZOLAN	Report No: Admixture No: AD 544(98) Date:

POZZOLAN CLASS:	DESCRIPTION: Silica Fume
COMPANY: Hanna Mining Co.	LOCATION: Wenatchee, WA
MEMO NO: 1985	DATE: 10/6/75 JOB NO: 545-C-530
MEMO SUBJECT: Variations in Cementitious Media	

CHEMICAL COMPOSITION

SiO_2 %	83.65	Moisture Content %	0.73	Cr_2O_3 %	0.04
Al_2O_3 %	0.51	LOI, % (750 C)	11.88	Chloride %	0.21
Fe_2O_3 %	0.37	LOI, % (1000 C)	11.03		
MgO %	0.44	TiO_2 %			
SO_3 %	0.36	P_2O_5 %			
CaO %	0.16	Mn_2O_3 %	0.00		

Alkalies %	Water Soluble	Available (C-618)	Acid Soluble	Total Alkali
Na_2O %		0.07	0.07	0.16
K_2O %		0.06	0.12	0.34
Total as Na_2O%		0.11	0.15	0.38

PHYSICAL TESTS

Specific Gravity: 2.16 Fineness % retained on 325 Sieve

Surface Area: 88,300 sqcm/cc, porosity e = 0.837

Tests with portland cement cured @ 73.4 $\pm$ 3 F

Portland Cement Co:	United					
Location:	Artesia, MS					
Research Cement No & Type:	RC-688(3), I, LA					
Autoclave Expansion, 20% Replacement, %						
% Replace of Cement by Volume	0	30	60	0	30	60
Heat of Hydration, 7 days, Cal/gm						
Heat of Hydration, 28 days, Cal/gm						
Compressive Strength, 3 days psi	2950	1830				
Compressive Strength, 7 days psi	4390	2680				
Compressive Strength, 28 days psi	6030	5740				
Compressive Strength, 90 days psi	6550	6780				
Compressive Strength, 180 days psi	7230	6800				
Compressive Strength, 365 days psi	6790	6540				
Water - Cement Ratio	0.485	0.65				
Flow	114	74				

Lime-Pozz Comp Str 375ml H_2O 71% Flow 1840 psi

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180	REPORT OF TESTS ON POZZOLAN	Report No: Admixture No: AD 545 Date:

POZZOLAN CLASS:	DESCRIPTION: Silica Fume	
COMPANY: Roane Electric	LOCATION: Rockwood, TN	
MEMO NO: 1985	DATE: 10/6/75	JOB NO: 545-C-530
MEMO SUBJECT: Variations in Cementitious Media		

CHEMICAL COMPOSITION

SiO_2 %	42.61	Moisture Content %	0.71	Cr_2O_3 %	0.02
Al_2O_3 %	4.73	LOI, % (750 C)	7.24	Chloride %	0.01
Fe_2O_3 %	6.22	LOI, % (1000 C)	9.14		
MgO %	2.85	TiO_2 %			
SO_3 %	2.12	P_2O_5 %			
CaO %	3.67	Mn_2O_3 %	22.62		

Alkalies %	Water Soluble	Available (C-618)	Acid Soluble	Total Alkali
Na_2O %		0.75	1.00	1.14
K_2O %		4.54	6.13	7.44
Total as Na_2O%		3.74	5.03	6.03

PHYSICAL TESTS

Specific Gravity: 2.79	Fineness	% retained on 325 Sieve				
Surface Area:	sqcm/cc, porosity	e =				
Tests with portland cement cured @ 73.4 $\pm$ 3 F						
Portland Cement Co:						
Location:						
Research Cement No & Type:						
Autoclave Expansion, 20% Replacement, %						
% Replace of Cement by Volume	0	30	60	0	30	60
Heat of Hydration, 7 days, Cal/gm						
Heat of Hydration, 28 days, Cal/gm						
Compressive Strength, 3 days psi						
Compressive Strength, 7 days psi						
Compressive Strength, 28 days psi						
Compressive Strength, 90 days psi						
Compressive Strength, 180 days psi						
Compressive Strength, 365 days psi						
Water - Cement Ratio						
Flow						

Lime Pozz Comp Str 240ml H_2O Flow 111% 510 psi

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180	REPORT OF TESTS ON POZZOLAN	Report No: Admixture No: AD 546 Date:

POZZOLAN CLASS:	DESCRIPTION: Silica Fume	
COMPANY: Foote Mineral	LOCATION: New Haven, WV	
MEMO NO: 1985	DATE: 10/6/75	JOB NO: 545-C-530
MEMO SUBJECT: Variations in Cementitious Media		

CHEMICAL COMPOSITION

SiO_2 %	73.73	Moisture Content %	0.00	Cr_2O_3 %	0.04
Al_2O_3 %	3.98	LOI, % (750 C)	1.01	Chloride %	0.06
Fe_2O_3 %	13.87	LOI, % (1000 C)	2.34		
MgO %	3.84	TiO_2 %			
SO_3 %	0.18	P_2O_5 %			
CaO %	2.32	Mn_2O_3 %	0.85		

Alkalies %	Water Soluble	Available (C-618)	Acid Soluble	Total Alkali
Na_2O %		0.15	0.22	0.44
K_2O %		0.20	0.22	1.17
Total as Na_2O%		0.28	0.36	1.21

PHYSICAL TESTS

Specific Gravity: 2.49 | Fineness % retained on 325 Sieve

Surface Area: sqcm/cc, porosity e =

Tests with portland cement cured @ 73.4 ± 3 F

Portland Cement Co:						
Location:						
Research Cement No & Type:						
Autoclave Expansion, 20% Replacement, %						
% Replace of Cement by Volume	0	30	60	0	30	60
Heat of Hydration, 7 days, Cal/gm						
Heat of Hydration, 28 days, Cal/gm						
Compressive Strength, 3 days psi						
Compressive Strength, 7 days psi						
Compressive Strength, 28 days psi						
Compressive Strength, 90 days psi						
Compressive Strength, 180 days psi						
Compressive Strength, 365 days psi						
Water - Cement Ratio						
Flow						

Lime-Pozz Comp Str 350ml H_2O 112% Flow 1320 psi

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180	REPORT OF TESTS ON POZZOLAN	Report No: Admixture No: AD 548 Date:

POZZOLAN CLASS:	DESCRIPTION: Silica Fume	
COMPANY: Airco	LOCATION: Calvert City, KY	
MEMO NO: 1985	DATE: 10/6/75	JOB NO: 545-C-530
MEMO SUBJECT: Variations in Cementitious Media		

CHEMICAL COMPOSITION

SiO_2 %	91.46	Moisture Content %	0.42	Cr_2O_3 %	0.01
Al_2O_3 %	1.00	LOI, % (750 C)	2.04	Chloride %	0.09
Fe_2O_3 %	1.50	LOI, % (1000 C)	2.37		
MgO %	0.70	TiO_2 %			
SO_3 %	0.17	P_2O_5 %			
CaO %	0.94	Mn_2O_3 %	0.23		

Alkalies %	Water Soluble	Available (C-618)	Acid Soluble	Total Alkali
Na_2O %		0.09	0.08	0.18
K_2O %		0.14	0.13	0.58
Total as Na_2O%		0.18	0.17	0.56

PHYSICAL TESTS

Specific Gravity: 2.37 | Fineness % retained on 325 Sieve

Surface Area: 27,700 sqcm/cc, porosity e = 0.711

Tests with portland cement cured @ 73.4 ± 3 F

Portland Cement Co:	United			Citadel		
Location:	Artesia, MS			Birmingham, AL		
Research Cement No & Type:	RC-688(3), II, LA			RC-705, II, LA, HH		
Autoclave Expansion, 20% Replacement, %						
% Replace of Cement by Volume	0	30	60	0	30	60
Heat of Hydration, 7 days, Cal/gm						
Heat of Hydration, 28 days, Cal/gm						
Compressive Strength, 3 days psi	2950*	2360		1700	1500	
Compressive Strength, 7 days psi	4390	2730		2510	1740	
Compressive Strength, 28 days psi	6030	5450		4040	4280	
Compressive Strength, 90 days psi	6550	6990		5760	5380	
Compressive Strength, 180 days psi	7230	6750		5990	5040	
Compressive Strength, 365 days psi	6790	6970			5150	
Water - Cement Ratio	0.485	0.602		0.485	0.602	
Flow	114	83		122	96	

Lime-Pozz 375ml H_2O 96% Flow 1790 psi

* 4 day compressive strength

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180	REPORT OF TESTS ON POZZOLAN	Report No: Admixture No: AD 549 Date:

POZZOLAN CLASS:	DESCRIPTION: Silica Fume
COMPANY: Union Carbide Metals	LOCATION: Sheffield, AL
MEMO NO: 1985	DATE: 10/6/75 — JOB NO: 545-C-530
MEMO SUBJECT: Variations in Cementitious Media	

CHEMICAL COMPOSITION

SiO_2 %	67.42	Moisture Content %	2.10	Cr_2O_3 %	0.05
Al_2O_3 %	4.84	LOI, % (750 C)	14.15	Chloride %	0.01
Fe_2O_3 %	11.29	LOI, % (1000 C)	14.38		
MgO %	1.94	TiO_2 %			
SO_3 %	0.32	P_2O_5 %			
CaO %	4.03	Mn_2O_3 %	1.78		

Alkalies %	Water Soluble	Available (C-618)	Acid Soluble	Total Alkali
Na_2O %		0.08	0.12	0.20
K_2O %		0.18	0.24	0.62
Total as Na_2O%		0.20	0.28	0.61

PHYSICAL TESTS

Specific Gravity: 2.25	Fineness % retained on 325 Sieve
Surface Area: 40,400 sqcm/cc, porosity e = 0.815	
Tests with portland cement cured @ 73.4 ± 3 F	
Portland Cement Co:	
Location:	
Research Cement No & Type:	
Autoclave Expansion, 20% Replacement, %	

% Replace of Cement by Volume	0	30	60	0	30	60
Heat of Hydration, 7 days, Cal/gm						
Heat of Hydration, 28 days, Cal/gm						
Compressive Strength, 3 days psi						
Compressive Strength, 7 days psi						
Compressive Strength, 28 days psi						
Compressive Strength, 90 days psi						
Compressive Strength, 180 days psi						
Compressive Strength, 365 days psi						
Water - Cement Ratio						
Flow						

Lime-Pozz 375ml H_2O 104% Flow 880 psi

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180	REPORT OF TESTS ON POZZOLAN	Report No: Admixture No: AD 550 Date:

POZZOLAN CLASS:	DESCRIPTION: Silica Fume	
COMPANY: Interlake Inc.	LOCATION: Beverly, OH	
MEMO NO: 1985	DATE: 10/6/75	JOB NO: 545-C-530
MEMO SUBJECT: Variations in Cementitious Media		

CHEMICAL COMPOSITION

SiO_2 %	67.40	Moisture Content %	1.11	Cr_2O_3 %	1.47
Al_2O_3 %	4.73	LOI, % (750 C)	4.76	Chloride %	4.14
Fe_2O_3 %	1.24	LOI, % (1000 C)	6.79		
MgO %	11.96	TiO_2 %			
SO_3 %	0.40	P_2O_5 %			
CaO %	0.67	Mn_2O_3 %	0.26		

Alkalies %	Water Soluble	Available (C-618)	Acid Soluble	Total Alkali
Na_2O %		1.78	2.77	2.60
K_2O %		1.29	2.51	3.09
Total as Na_2O%		2.63	4.42	4.63

PHYSICAL TESTS

Specific Gravity: 2.36	Fineness % retained on 325 Sieve
Surface Area: 39,600 sqcm/cc, porosity	e = 0.782

Tests with portland cement cured @ 73.4 ± 3 F

Portland Cement Co:						
Location:						
Research Cement No & Type:						
Autoclave Expansion, 20% Replacement, %						
% Replace of Cement by Volume	0	30	60	0	30	60
Heat of Hydration, 7 days, Cal/gm						
Heat of Hydration, 28 days, Cal/gm						
Compressive Strength, 3 days psi						
Compressive Strength, 7 days psi						
Compressive Strength, 28 days psi						
Compressive Strength, 90 days psi						
Compressive Strength, 180 days psi						
Compressive Strength, 365 days psi						
Water - Cement Ratio						
Flow						

Lime-Pozz 225ml H_2O 83% Flow 1640 psi

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180	REPORT OF TESTS ON POZZOLAN	Report No: Admixture No: AD 551 Date:

POZZOLAN CLASS:	DESCRIPTION: Silica Fume		
COMPANY: Interlake, Inc.	LOCATION: Beverly, OH	Sample No. 2	
MEMO NO: 1985	DATE: 10/6/75	JOB NO: 545-C-530	
MEMO SUBJECT: Variations in Cementitious Media			

CHEMICAL COMPOSITION

SiO_2 %	93.58	Moisture Content %	0.34	Cr_2O_3 %	0.00
Al_2O_3 %	0.60	LOI, % (750 C)	3.45	Chloride %	0.05
Fe_2O_3 %	0.26	LOI, % (1000 C)	3.74		
MgO %	1.01	TiO_2 %			
SO_3 %	0.50	P_2O_5 %			
CaO %	0.44	Mn_2O_3 %	0.02		

Alkalies %	Water Soluble	Available (C-618)	Acid Soluble	Total Alkali
Na_2O %		0.03	0.05	0.10
K_2O %		0.10	0.13	0.71
Total as Na_2O%		0.10	0.14	0.57

PHYSICAL TESTS

Specific Gravity: 2.25	Fineness	% retained on 325 Sieve
Surface Area: 163,000	sqcm/cc, porosity	e = 0.842

Tests with portland cement cured @ 73.4 $\pm$ 3 F

Portland Cement Co:						
Location:						
Research Cement No & Type:						
Autoclave Expansion, 20% Replacement, %						
% Replace of Cement by Volume	0	30	60	0	30	60
Heat of Hydration, 7 days, Cal/gm						
Heat of Hydration, 28 days, Cal/gm						
Compressive Strength, 3 days psi						
Compressive Strength, 7 days psi						
Compressive Strength, 28 days psi						
Compressive Strength, 90 days psi						
Compressive Strength, 180 days psi						
Compressive Strength, 365 days psi						
Water - Cement Ratio						
Flow						

Lime-Pozz Comp Str 385ml H_2O 64% Flow 2130 psi

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180	REPORT OF TESTS ON POZZOLAN	Report No: Admixture No: AD 552 Date:

POZZOLAN CLASS:	DESCRIPTION: Silica Fume	
COMPANY: Airco	LOCATION: Niagara Falls, NY	
MEMO NO: 1985	DATE: 10/6/75	JOB NO: 545-C-530
MEMO SUBJECT: Variations in Cementitious Media		

CHEMICAL COMPOSITION

SiO_2 %	93.32	Moisture Content %	0.54	Cr_2O_3 %	0.10
Al_2O_3 %	1.59	LOI, % (750 C)	1.44	Chloride %	
FeO_3 %	0.95	LOI, % (1000 C)	2.09		
MgO %	1.09	TiO_2 %			
SO_3 %	0.04	P_2O_5 %			
CaO %	0.48	Mn_2O_3 %	0.08		

Alkalies %	Water Soluble	Available (C-618)	Acid Soluble	Total Alkali
Na_2O %		0.06	0.05	0.17
K_2O %		0.22	0.21	1.72
Total as Na_2O%		0.20	0.19	1.30

PHYSICAL TESTS

Specific Gravity: 2.23 | Fineness | % retained on 325 Sieve

Surface Area: 74,600 sqcm/cc, porosity e = 0.811

Tests with portland cement cured @ 73.4 $\pm$ 3 F

Portland Cement Co:						
Location:						
Research Cement No & Type:						
Autoclave Expansion, 20% Replacement, %						
% Replace of Cement by Volume	0	30	60	0	30	60
Heat of Hydration, 7 days, Cal/gm						
Heat of Hydration, 28 days, Cal/gm						
Compressive Strength, 3 days psi						
Compressive Strength, 7 days psi						
Compressive Strength, 28 days psi						
Compressive Strength, 90 days psi						
Compressive Strength, 180 days psi						
Compressive Strength, 365 days psi						
Water - Cement Ratio						
Flow						

Lime-Pozz Comp Str 330ml H_2O 86 % Flow 2270 psi

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180	REPORT OF TESTS ON POZZOLAN	Report No: Admixture No: AD 553 Date:

POZZOLAN CLASS:	DESCRIPTION: Silica Fume	
COMPANY: Airco	LOCATION: Niagara, NY	
MEMO NO: 1985	DATE: 10/6/75	JOB NO: 545-C-530
MEMO SUBJECT: Variations in Cementitious Media		

CHEMICAL COMPOSITION

SiO_2 %	80.71	Moisture Content %	0.77	Cr_2O_3 %	0.66
Al_2O_3 %	3.62	LOI, % (750 C)	1.69	Chloride %	0.08
Fe_2O_3 %	0.57	LOI, % (1000 C)	3.40		
MgO %	9.86	TiO_2 %			
SO_3 %	0.34	P_2O_5 %			
CaO %	0.32	Mn_2O_3 %	0.14		

Alkalies %	Water Soluble	Available (C-618)	Acid Soluble	Total Alkali
Na_2O %		0.18	0.17	0.48
K_2O %		0.33	0.36	1.58
Total as Na_2O%		0.40	0.41	1.52

PHYSICAL TESTS

Specific Gravity: 2.29 | Fineness % retained on 325 Sieve

Surface Area: 55,400 sqcm/cc, porosity e = 0.821

Tests with portland cement cured @ 73.4 ± 3 F

Portland Cement Co:						
Location:						
Research Cement No & Type:						
Autoclave Expansion, 20% Replacement, %						
% Replace of Cement by Volume	0	30	60	0	30	60
Heat of Hydration, 7 days, Cal/gm						
Heat of Hydration, 28 days, Cal/gm						
Compressive Strength, 3 days psi						
Compressive Strength, 7 days psi						
Compressive Strength, 28 days psi						
Compressive Strength, 90 days psi						
Compressive Strength, 180 days psi						
Compressive Strength, 365 days psi						
Water - Cement Ratio						
Flow						

Lime-Pozz **360ml H_2O** **95% Flow** **1960 psi**

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180	REPORT OF TESTS ON POZZOLAN	Report No: Admixture No: AD 557 Date:

POZZOLAN CLASS:	DESCRIPTION: Silica Fume	
COMPANY: Union Carbide	LOCATION: Sheffield, AL	
MEMO NO: 1985	DATE: 10/6/75	JOB NO: 545-C-530
MEMO SUBJECT: Variations in Cementitious Media		

CHEMICAL COMPOSITION

SiO_2 %	71.17	Moisture Content %	0.22	Cr_2O_3 %	0.01
Al_2O_3 %	2.44	LOI, % (750 C)	11.25	Chloride %	0.17
FeO_3 %	14.60	LOI, % (1000 C)	11.00		
MgO %	0.46	TiO_2 %			
SO_3 %	0.24	P_2O_5 %			
CaO %	1.10	Mn_2O_3 %	0.93		

Alkalies %	Water Soluble	Available (C-618)	Acid Soluble	Total Alkali
Na_2O %		0.08	0.12	0.19
K_2O %		0.18	0.16	0.63
Total as Na_2O%		0.20	0.23	0.60

PHYSICAL TESTS

Specific Gravity: 2.48 | Fineness % retained on 325 Sieve

Surface Area: 142,600 sqcm/cc, porosity e = 0.840

Tests with portland cement cured @ 73.4 ± 3 F

Portland Cement Co:						
Location:						
Research Cement No & Type:						
Autoclave Expansion, 20% Replacement, %						
% Replace of Cement by Volume	0	30	60	0	30	60
Heat of Hydration, 7 days, Cal/gm						
Heat of Hydration, 28 days, Cal/gm						
Compressive Strength, 3 days psi						
Compressive Strength, 7 days psi						
Compressive Strength, 28 days psi						
Compressive Strength, 90 days psi						
Compressive Strength, 180 days psi						
Compressive Strength, 365 days psi						
Water - Cement Ratio						
Flow						

Lime-Pozz **340ml H_2O** **60% Flow** **1630 psi**

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180	REPORT OF TESTS ON POZZOLAN	Report No: Admixture No: AD 558 Date:

POZZOLAN CLASS:	DESCRIPTION: Silica Fume	
COMPANY: Hanna Mining	LOCATION: Wenatchee, WA	
MEMO NO: 1985	DATE: 10/6/75	JOB NO: 545-C-530
MEMO SUBJECT: Variations in Cementitious Media		

CHEMICAL COMPOSITION

SiO_2 %	85.06	Moisture Content %	0.58	Cr_2O_3 %	0.00
Al_2O_3 %	1.73	LOI, % (750 C)	4.26	Chloride %	1.06
FeO_3 %	1.81	LOI, % (1000 C)	5.43		
MgO %	1.50	TiO_2 %			
SO_3 %	0.30	P_2O_5 %			
CaO %	0.68	Mn_2O_3 %	0.31		

Alkalies %	Water Soluble	Available (C-618)	Acid Soluble	Total Alkali
Na_2O %		0.60	0.84	1.24
K_2O %		0.54	0.92	2.27
Total as Na_2O%		0.96	1.45	2.73

PHYSICAL TESTS

Specific Gravity: 2.25	Fineness	% retained on 325 Sieve
Surface Area: 99,000	sqcm/cc, porosity	e = 0.825

Tests with portland cement cured @ 73.4 ± 3 F

Portland Cement Co:						
Location:						
Research Cement No & Type:						
Autoclave Expansion, 20% Replacement, %						
% Replace of Cement by Volume	0	30	60	0	30	60
Heat of Hydration, 7 days, Cal/gm						
Heat of Hydration, 28 days, Cal/gm						
Compressive Strength, 3 days psi						
Compressive Strength, 7 days psi						
Compressive Strength, 28 days psi						
Compressive Strength, 90 days psi						
Compressive Strength, 180 days psi						
Compressive Strength, 365 days psi						
Water - Cement Ratio						
Flow						

Lime-Pozz Comp Str 340ml 88% Flow 910

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180	REPORT OF TESTS ON POZZOLAN	Report No: Admixture No: AD 560 Date:

POZZOLAN CLASS: F	DESCRIPTION: Fly Ash Enhanced	
COMPANY: Amax	LOCATION: Smyrna, GA	
MEMO NO: 1985	DATE: 10/6/75	JOB NO: 545-C-530
MEMO SUBJECT: Variations in Cementitious Media		

CHEMICAL COMPOSITION

SiO_2 %	53.17	Moisture Content %	0.52	Cr_2O_3 %	
Al_2O_3 %	31.08	LOI, % (750 C)	1.29	Chloride %	
FeO_3 %	5.25	LOI, % (1000 C)			
MgO %	1.40	TiO_2 %			
SO_3 %	0.25	P_2O_5 %			
CaO %	2.78	Mn_2O_3 %			

Alkalies %	Water Soluble	Available (C-618)	Acid Soluble	Total Alkali
Na_2O %	0.001	0.12		0.43
K_2O %	0.001	0.94		3.50
Total as Na_2O%	0.00	0.74		2.73

PHYSICAL TESTS

Specific Gravity: 2.60 | Fineness % retained on 325 Sieve

Surface Area: 20,800 sqcm/cc, porosity e =

Tests with portland cement cured @ 73.4 ± 3 F

Portland Cement Co:	Citadel					
Location:	Birmingham, AL					
Research Cement No & Type:	RC-705, II, LA, HH					
Autoclave Expansion, 20% Replacement, %	-0.02					
% Replace of Cement by Volume	0	30	60	0	30	60
Heat of Hydration, 7 days, Cal/gm						
Heat of Hydration, 28 days, Cal/gm						
Compressive Strength, 3 days psi						
Compressive Strength, 7 days psi						
Compressive Strength, 28 days psi						
Compressive Strength, 90 days psi						
Compressive Strength, 180 days psi						
Compressive Strength, 365 days psi						
Water - Cement Ratio						
Flow						

Lime Pozz Str 173ml H_2O, Flow 107% 2000 psi

Pozzolanic Activity Index with Portland Cement (RC-705)
Portland Cement Compressive Strength 4750 psi (Control)
Portland Cement + Pozzolan Compress Strength 6730 psi (142% of Control)

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180	REPORT OF TESTS ON POZZOLAN	Report No: Admixture No: AD 570 Date:

POZZOLAN CLASS: F	DESCRIPTION: Fly Ash	
COMPANY: Trinity	LOCATION: Purvis, MS	
MEMO NO: 1985	DATE: 10/6/75	JOB NO: 545-C-530
MEMO SUBJECT: Variations in Cementitious Media		

CHEMICAL COMPOSITION

SiO_2 %	47.81	Moisture Content %	0.16	Cr_2O_3 %	
Al_2O_3 %	30.61	LOI, % (750 C)	3.70	Chloride %	
Fe_2O_3 %	7.59	LOI, % (1000 C)			
MgO %	1.11	TiO_2 %			
SO_3 %	0.60	P_2O_5 %			
CaO %	2.14	Mn_2O_3 %			

Alkalies %	Water Soluble	Available (C-618)	Acid Soluble	Total Alkali
Na_2O %		0.12		0.37
K_2O %		0.94		2.78
Total as Na_2O%		0.74		2.20

PHYSICAL TESTS

Specific Gravity:	2.25	Fineness	% retained on 325 Sieve
Surface Area:	13,750	sqcm/cc, porosity	e = 0.519

Tests with portland cement cured @ 73.4 $\pm$ 3 F

Portland Cement Co:	United			Citadel		
Location:	Artesia, MS			Birmingham, AL		
Research Cement No & Type:	RC-688 (3)			RC-705, II, LA, HH		
Autoclave Expansion, 20% Replacement, %				0.03		
% Replace of Cement by Volume	0	30	60	0	30	60
Heat of Hydration, 7 days, Cal/gm						
Heat of Hydration, 28 days, Cal/gm						
Compressive Strength, 3 days psi	2950	2050	590	1700	960	
Compressive Strength, 7 days psi	4390	2920	1140	2510	1840	
Compressive Strength, 28 days psi	6030	4430	2060	4040	3700	
Compressive Strength, 90 days psi	6550	6010	3610	5760	5790	
Compressive Strength, 180 days psi	7230			5990		
Compressive Strength, 365 days psi	6790					
Water - Cement Ratio	0.485	0.513	0.552	0.485	0.500	
Flow	114	112	105	122	115	

Lime Pozz Str 175ml H20 Flow 106% 1550 psi
Pozzolanic Acitivity Index with Portland Cement (RC-705)
Portland Cement Compressive Strength 4590 psi (Control)
Portland Cement + Pozzolan Compressive Strength 5280 psi (115% of Control)

W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

LABORATORY: Mrs. K. Mather C/Engrg Sci Div Structures Laboratory	REPORT OF TESTS ON POZZOLAN (CRD-C 262) AD-577	REPORT NO.: WES-295F-78 SHEET 1 OF 1 DATE: 24 Nov 78

CLASS (F) N — KIND OF POZZOLAN: Fly Ash

SOURCE: TXI, Big Brown, Fairfield, TX — BRAND:

TEST RESULTS OF THIS SAMPLE LOT ☐ COMPLY ☐ DO NOT COMPLY WITH SPECIFICATION LIMITS (SEE REMARKS)

FOR USE AT:

CONTRACT NO.:

DISTRICT(S):

SAMPLED BY: — DATE SAMPLED:

CAR NO.: — BIN NO.:

FIELD SAMPLE NO.: — LAB SAMPLE NO.:

DATE RECEIVED: — LAB JOB NO.:

TESTED BY: — CHECKED BY:

TESTS ON COMPOSITE OF THE 100-TON SAMPLES LISTED BELOW

$SiO_2 + Al_2O_3 + Fe_2O_3$ %	MgO %	SO_3 %	AVAILABLE ALKALIES %	POZZOLAN STRENGTH % CONTROL	INCREASE IN SHRINKAGE % (a)	AUTOCLAVE EXPANSION %	REDUCTION IN EXPANSION % (b)
REQUIREMENTS							
MIN 70.0	MAX 5.0	MAX 4.0	MAX 1.5	MIN 75	MAX 0.03	MAX 0.50	MIN 75
TEST RESULTS							
71.37	3.79	1.7	0.51				

TESTS ON SAMPLES REPRESENTING 100 TONS OR LESS

SAMPLE NO.	MOISTURE CONTENT %	LOSS ON IGNITION %	AIR PERMEABILITY FINENESS SQ CM/CC (AVERAGE)	FINENESS VARIATION FROM AVERAGE OR PRECEDING 10, %	LIME POZZOLAN STRENGTH PSI	WATER REQUIREMENT INCREASE IN FLOW %	SPECIFIC GRAVITY	
REQUIREMENTS								
—	MAX 3.0	MAX 10.0 (N) 6.0 (F)	MIN 6500	MAX 20	MIN 900	MIN 0	—	
TEST RESULTS								
	0.16	0.60		Alkalies				Total as
				Available:				Na_2O%
SiO_2:	44.51%			K_2O:	0.27%			
				Na_2O:	0.33%			0.51
Al_2O_3:	20.42%			Water Soluble				
Fe_2O_3:	5.96%			K_2O:	0.001%			
				Na_2O:	0.072%			0.071
CaO :	19.91%							
				Total Alkali				
				K_2O:	0.76%			
AVERAGE	—	—		Na_2O:	0.65%			1.15

(a) APPLICABLE ONLY TO CLASS N — LABORATORY CEMENT USED

(b) OPTIONAL REQUIREMENT — LABORATORY LIME USED

REMARKS: Ref. ltr from TXI, Midlothian, TX dtd 4/5/78
This pozzolan blended with RC-807 (A) to make RC-807
Sample size approximately 4oz

Ronald E. Reinhold
for W.G. MILLER
Chemist
Chief, Cement & Pozzolan Test Br.

NOTE: THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U. S. GOVERNMENT.

ENG FORM NO 6000-R AUG 67

END

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